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[THIRD SERIES.]

ART. XXII.—*The Absolute Wave-length of Light;* by LOUIS BELL.

THIS paper contains the final results of the research partially reported in this journal for March 1886. In view of the wide discrepancies in the value of this physical constant as determined by various observers and methods, it has seemed desirable to give in brief the history of the subject, and critically to discuss certain portions of the investigation which have proved stumbling-blocks in the past. I refer particularly to the verification of the standards of length employed, and to those errors of ruling in the gratings which may, and usually do, produce errors in the result obtained.

The first portion of this paper will be devoted to the methods and results of the pioneers in this work and the methods, apparatus, and standards of length employed in the present investigation.

The second portion will contain the details of the experimental work, together with a discussion of the final results and those questions of theoretical and practical interest which raise themselves in connection with the work of recent experimenters. With this preliminary notice is presented the first half of the paper.

Historical.—Fraunhofer's first paper on the lines which bear his name marks a new era in the science of optics. Up

to that point any careful study of spectra had been impossible for lack of definite standards of reference, and because the apparatus was as yet very defective. Fraunhofer's research, "Bestimmung des Brechungs- und Farbenzerstreuungs-Vermögens verschiedener Glasarten," was presented to the Munich Academy of Sciences in 1814, and was published in the fifth volume of the "Denkschriften." It then became possible to study in detail the properties of rays of definite position and the work was taken up almost immediately. Almost the first step was to determine the wave-lengths of prominent points in the solar spectrum, and, as is well known, Fraunhofer himself took it, determining the wave-lengths corresponding to his lines B, C, D, E, F, G, H. As there seems to have been—noticeably in Verdet's papers—some confusion concerning his papers on this subject, it may be well here to clear the matter up.

Fraunhofer's first paper dealing with the subject was presented to the Munich Academy in 1821. It is entitled: "Neue Modifikation des Lichtes durch gegenseitige Einwirkung und Beugung der Strahlen, und Gesetze derselben," and was printed in the eighth volume of the "Denkschriften." It is of considerable length and deals with various diffraction phenomena, but its chief interest lies in the wave length measurements made with wire gratings. The experiments made with ten of these are given in detail and are remarkably careful and consistent. The gratings were quite various, the wires being from $0{\cdot}04^{mm}$ to $0{\cdot}6^{mm}$ in thickness and the grating space as ordinarily measured, from 0·0528 to $0{\cdot}6866^{mm}$. From these proportions it is evident enough that the spectra must have been very imperfect, but in spite of this, Fraunhofer obtained results which agreed remarkably well with each other. The wave lengths of D as obtained from the above mentioned ten gratings were as follows: reduced to millimeters.

	mm		mm
(1)	0·0005891	(6)	0·0005888
(2)	0·0005894	(7)	0·0005885
(3)	0·0005891	(8)	0·0005885
(4)	0·0005897	(9)	0·0005882
(5)	0·0005885	(10)	0·0005882

The mean value adopted was $0{\cdot}0005888^{mm}$, which considering the gratings and the fact that most of the angles of deviation were less than 1°, is certainly remarkably accurate. It should be noted too, that the finer gratings (1) to (4) gave even better results.

A brief discussion of this paper appeared in the seventy-third volume of Gilbert's Annalen and a French reprint in Schumacher's Astronomische Abhandlungen (ii, 46).

Fraunhofer's second and more complete paper appeared in 1823 in Gilbert's Annalen (lxxiv, 337). Its title is: "Kurzer Bericht von den Resultaten neuerer Versuche über die Gesetze des Lichtes, und die Theorie derselben." This paper gives a detailed account of his experiments with two glass gratings. Of these, the grating spaces were respectively 0·0033 and 0·0160^{mm}. The former was apparently much the better, and upon it Fraunhofer based his final result, which for D was 0·0005886^{mm} while the experiments with the coarser grating gave 0·0005890^{mm}. These values apply quite certainly to the mean of the two D lines, and not, as has been sometimes supposed, to one of them alone.

The experimental work with these glass gratings was much better than with the previous wire ones, since the angular deflections were very much larger and the gratings themselves were susceptible of far more exact measurement. But at best they were but indifferent instruments and the terminal lines were so bad that they had to be retraced before the grating space could be determined. So, between poor gratings and indifferent standards of length, Fraunhofer's determination of absolute wave length left very much to be desired. However, nothing much better could be accomplished until the art of making gratings was very much improved, and it was not until Nobert's gratings became tolerably well known, that any serious attempt was made to improve on Fraunhofer's results. From time to time various investigators worked on the problem, both with Nobert's earlier gratings and by utilizing various interference phenomena. When, however, the great investigations of Bunsen and Kirchhoff revolutionized spectroscopic work and emphasized its great importance, the attention of scientific men was called to the need for accurate measurements, and for half a dozen years investigators were active, and Mascart, Ditscheiner and Ångström appeared on the field almost simultaneously. Each published a paper in 1864, and of these that of Mascart is probably the most accurate and painstaking, though now it is quite certain that the values he obtained were considerably too small. He employed four or five of Nobert's gratings and instead of placing the grating perpendicular to either the collimator or the observing telescope, used it in the position of minimum deviation, that is to say, so that the plane of the grating should bisect the angle formed by the incident and diffracted rays. This position has certain advantages, but as the experimentation is rather more difficult than in the ordinary position, the method appears to be of somewhat questionable utility. It avoids, to be sure, the necessity of placing the grating normal to the axis of either telescope, but as there is very little trouble in making this ad-

justment with a high degree of accuracy, and keeping it through a series of measurements, the gain is by no means considerable. Aside from this question, Mascart's spectrometer read only to five seconds, and while his results with different gratings agree very well individually they are certainly collectively in error by quite a large amount, very possibly owing to bad standards of length.

It is a fact to be noted in discussing all these earlier wave-length determinations, that sufficient attention was not paid to the measurement and study of the gratings—by all odds the most difficult part of the problem. The angular measures of any one of the above investigators were good enough to have given very exact results had they been combined with proper investigations of the grating spaces. As most of Nobert's gratings were small and by no means accurately ruled there was peculiar need of care in measuring them, and when one considers that the defining lines on most standards of length are far from being good, it is clear that the chances for error were numerous. In Ångström's first paper he even relied on the grating space assigned by the maker. Ditscheiner employed a grating which had belonged to Fraunhofer himself, but the number of spaces was uncertain and this led to a large error which he corrected, in part, in a supplementary paper some years later. Ditscheiner's principal paper was published in 1866, and was followed in 1868 by an elaborate discussion of the whole problem by van der Willigen, whose paper is valuable mainly for a particularly elaborate review of sources of error. Like his predecessors he used Nobert's gratings, but as the construction of his spectrometer confined his angular measurements to the deviation on one side of the normal, their accuracy may be open to some question, while his standard of length was anything but reliable, as it was a glass scale only three centimeters long and the only assurance of its accuracy was the certificate of the maker that it was "tres exacte" at 50° Centigrade. For one or both of the above reasons van der Willigen's results were larger than any which have been obtained, before or since his time.

In the same year appeared Ångström's great research which has so long served as the standard in all questions of wave length. It is hard to say too much of the conscientious and painstaking experiments on which his results were based, and any want of accuracy in the final result was due to no lack of skill or care on his part but rather to the imperfect instruments with which he was obliged to work. Like every one before him he used Nobert's gratings and in spite of the fact that like all Nobert's gratings they gave very imperfect definition and showed numerous "ghosts," his results were more than usually

consistent. But in spite of all Ångström's care the event has shown that his wave lengths are in error by as much as one part in seven or eight thousand mainly through an error in the assumed values of his standards of length. Ångström measured his gratings by means of a dividing engine the screw of which was very exactly determined by comparisons resting on the Upsala meter which, in turn, had been compared by M. Tresca with the prototype of the Conservatoire des Arts et Metiers. Had this comparison given the correct value of the Upsala meter Ångström's wave-lengths would have been very nearly exact except for corrections due to errors of ruling in the gratings.

After Ångström's research the question of absolute wave-length was not seriously raised for ten years, when Mr. C. S. Peirce under the auspices of the United States Coast Survey again attacked the problem, armed with Rutherfurd gratings far superior to those used in any previous research. No official report of his very elaborate and exhaustive experiments has ever been published save a very brief preliminary report in the American Journal of Science in 1879. Such of his results as have been made in any way public will be discussed in the experimental part of the present paper.

Meanwhile Thalén, who so efficiently aided Ångström in his work, has taken up the part of it left uncompleted by the latter's death and in his paper "Sur le Spectre du Fer," published at Upsala in 1885, has discussed the corrections which must be applied to Ångström's values by reason of the error in the Upsala meter. It seems that through the experiments of Professor Lindhagen, Ångström became aware as early as 1872 that the assumed value of his standard was considerably too small. His death prevented his verification of M. Lindhagen's results and nothing further was done till Thalén took up the work. Tresca's comparisons had shown that the true length of the Upsala metre at 0° was 999·81^{mm}. But the very exact experiments of M. Lindhagen have shown the above to be somewhat too small and that the correct value is 999·94. This difference makes, of course, a marked error in the wave-lengths based on Tresca's results. Applying the appropriate correction, the wave length of E, the line most carefully determined by Ångström, becomes

5269·80,

instead of the original 5269·12.

This final result of Ångström is certainly entitled to considerable respect and seems to be subject only to those corrections which may be due to irregularities in the gratings. These were, however, so poor compared with the gratings of to-day,

that such corrections would necessarily be of uncertain magnitude.

At all events it is quite sure that of the wave-length determinations made up to 1880, those of Peirce, and Ångström corrected by Thalén are by all odds the best. Of the two, Peirce's is probably the better by reason of better gratings, but his work will be discussed in another part of this paper in connection with the very recent works of Müller and Kempf and Kurlbaum, which merit more extended study than would be in place at this point.

A tolerably complete bibliography of the subject up to date is annexed. Many of the papers are of little except historical value, but they will at least exhibit the various methods employed and the growth of exact experimentation.

1821	Fraunhofer.	Denkschr. d. Akad. d. Wiss. zu München, viii, Heft. II, 38. "Neue Modifikation des Lichtes durch gegenseitige Einwirkung und Beugung der Strahlen und Gesetze derselben."
1823	Fraunhofer.	Schumacher's astronomische Abhandlungen, ii, 46.
1823	Fraunhofer.	Gilbert's Annalen, lxxiv, 337. "Kurzer Bericht von den Resultaten neuerer Versuche über die Gesetze des Lichtes und die Theorie derselben."
1835	Schwerd.	"Die Beugungserscheinungen" (Mannheim).
1849	Stokes.	Athenæum No. 1143. Inst. xvii, 368. "On the Determination of the Wave Length corresponding with any Point of the Spectrum."
1851	Nobert.	Proc. Roy. Soc., vi, 43; Phil. Mag., IV, i, 570. "Description and Purpose of the Glass Plate which bears the Inscription: Longitudo et celeritas undularum lucis cum in aere tum in vitro."
1851	Nobert.	Pogg. Ann., lxxxv, 83. "Ueber eine Glasplatte mit Theilungen zur Bestimmung der Wellenlänge und relativen Geschwindigkeit des Lichts in der Luft und im Glase."
1852	Drobisch.	Pogg. Ann., lxxxviii, 519. "Ueber die Wellenlänge und Oscillationszahlen der farbigen Strahlen im Spectrum."
1853	Esselbach.	Berlin Monatsber. 757. "Ueber die Messung der Wellenlänge des ultravioletten Lichts."
1856	Esselbach.	Pogg. Ann., xcviii, 513. Ann. de Chim. e. d. Phys., III, l, 121, "Eine Wellenmessung im Spectrum jenseits des Violetts."
1856	Eisenlohr.	Pogg. Ann., xcviii, 353, xcix, 159. Ann. de Chim. e. d. Phys., III, xlix, 504. "Die brechbarsten oder unsichtbaren Lichtstrahlen in Beugungspectrum und ihre Wellenlänge."
1863	Müller.	Pogg. Ann., cxviii, 641. "Bestimmung der Wellenlänge einiger heller Spectrallinien."
1863	Mascart.	C. R., lvi, 138. "Détermination de longueur d'onde de la raie A."
1864	Mascart.	C. R., lviii, 1111. Détermination des longueurs d'onde des rayons lumineux et des rayons ultraviolets.
1864	Mascart.	Ann. de l'École normale, i, 219, Recherches sur la détermination des longueurs d'onde
1864	Bernard.	Mondes, v, 181. "Theorie des bandes d'interférence * * * Longueur d'onde de la raie A." * * *
1864	Stefan.	Ber. d. Wien. Acad., l, Heft 2, 31. Pogg. Ann., cxxii, 631. "Ueber die Dispersion des Lichtes durch Drehung der Polarizationsebene im Quarz."
1864	Bernard.	C. R., lviii, 1153; lix, 352. "Memoire sur la détermination des longueurs d'onde des raies du spectre solaire au moyen des bandes d'interférence."

1864	Ditscheiner.	Ber. d. Wien. Acad., l. Heft 2. 296. "Bestimmung der Wellen länge der Fraunhofer'schen Linien des Sonnenspectrums."
1864	Ångström.	Pogg. Ann., cxxiii, 489. Œfvers. af Förhandl. (1863) 41. "Neue Bestimmung der Länge der Lichtwellen nebst eine Methode auf Optischen Wege die fortschreitende Bewegung des Sonnensystems zu bestimmen."
1866	Ditscheiner.	Ber. d. Wien. Acad., lii. Heft 2. 289. "Eine absolute Bestimmung der Wellenlänge der Fraunhofer'schen D Linien."
1866	Mascart.	Ann. de l'Ecole normale, iv, 7. "Recherches sur la détermination des longueurs d'onde."
1868	Mascart.	Ann. de Chim. e. d. Phys., IV, xiii, 186. "Note sur différents travaux relatifs aux longueurs d'onde."
1868	van der Willigen.	Arch. du Musée Teyler. i. 1, 57, 280. "Memoire sur la Détermination des longueurs d'onde du Spectre Solaire."
1868	Ångström.	Upsala, 1868. "Recherches sur le Spectre Solaire."
1871	Ditscheiner.	Ber. d. Wien. Acad., lxiii, heft 2. 265. "Zur Bestimmung der Wellenlänge der Fraunhofer'schen Linien."
1879	Peirce.	Am. Jour. Sci., III, xviii, 51. "Note on the Progress of Experiments for comparing a Wave length with a Metre."
1884	Thalén.	Upsala, 1885. "Sur le Spectre du Fer obtenu a l'aide de l'arc électrique," p. 18.
1886	Müller and Kempf.	Publicationen des Astrophysikalischen Observatoriums zu Potsdam, v. "Bestimmung der Wellenlänge von 300 Linien im Sonnenspectrum."
1886	de Lépinay.	Jour. de Ph., II, v, 411. "Détermination de la valeur absolue de la longueur d'onde de la raie D^2."
1887	Bell.	Am. Jour. Sci., III, xxxii, 167. "On the absolute Wave length of Light."
1887	Kurlbaum.	Berlin, 1887. "Bestimmung der Wellenlänge einiger Fraunhofer'schen Linien."

In general the determination of absolute wave-length involves two quite distinct problems—first the precise determination of some quantity which is an exact function of the wave-length and some other linear dimension; and second, the reduction of this dimension to terms of some recognized standard of length. The first process can be made to give relative wave-lengths with a very high degree of accuracy, and is, in nearly every case, more exact than the second, which constitutes the main difficulty of the investigation. It is because the diffraction grating lends itself readily to linear measurement, that its use is preferable to the other interference methods which involve, usually, the exact determination of a single very small linear quantity. The ingenious attempt of M. de Lépinay* to avoid this difficulty is interesting theoretically but practically it involves a quantity even more uncertain than the average standard of length—the relation between the kilogram and the meter—to say nothing of the experimental difficulties of the method. The angular measurements of nearly all the later investigators have been quite good enough to furnish very exact values of wave-length, but in every case it has been the measurement of the grating space that has produced the manifold errors and discrepancies

* Journ. Phys., II, v, 411.

in the results. It has been the aim of the present research to investigate this fruitful source of errors and as far as possible to avoid the difficulties springing from it.

In a previous paper,* I briefly discussed the advantages of transmission and reflection gratings. It only remains to add that further experience has convinced me that not only are the speculum metal gratings far superior in brilliancy and sharpness of definition, but that it is possible, contrary to what one might suppose from their large coefficient of expansion, to rule them with almost perfect uniformity, over a length as great as a decimeter. This large size too, gives a great advantage in determining the grating space, aside from the fact that speculum metal has a coefficient of expansion not widely different from that of any one of the materials usually employed for standards of length, and that its temperature can be obtained with comparative ease.

Methods and Instruments.

The plane grating can be used for wave-length measurement in a variety of ways according to the preference of the investigator or the arrangement of the spectrometer. Five tolerably distinct methods may be enumerated. The general relation between the wave-length and the angles of incidence and diffraction is

$$\lambda = s(\sin i + \sin(\varphi - i))\frac{1}{n}$$

Where λ is the wave-length, s the grating space, i and φ the angles of incidence and diffraction respectively, and n the order of the spectrum observed. Making $i=0°$ this at once becomes the ordinary formula

$$\lambda = \frac{1}{n} s \sin \varphi$$

which applies to the two methods of normal incidence, one in which the grating is kept accurately perpendicular to the collimator; the other in which it is kept perpendicular to the observing telescope.

Next is the method used by Ångström in which i is not reduced exactly to 0°, but measured and retained in the formula, the grating in this case being kept nearly perpendicular to the collimator. In this method a reading on the slit is necessary, and if α and α' are the readings on the circle, and M that on the slit, the working formulæ are:

$$\frac{\alpha + \alpha'}{\alpha} - \mathrm{M} = \delta \text{ and } \frac{\alpha - \alpha'}{2} = \varphi$$

* Am. Jour. Sci., III, xxxiii, 167.

then, if i is as before, the angle of incidence,

$$\lambda = \frac{1}{n} s \sin \varphi \cos (i + \delta)$$

$$\sin i = \sin(i + \delta) \cos \varphi$$

$$\tan i = \frac{\cos \varphi}{1 - \cos \varphi} \delta$$

In the fourth method also, i is retained, but given a definite value. Putting the general formula in the form,

$$\lambda = \frac{1}{n} 2 s \sin \frac{\varphi}{2} \cos\left(i - \frac{\varphi}{2}\right)$$

the deviation represented by the angular term will evidently be a minimum when $i = \frac{\varphi}{2}$. If then one observes in the position of minimum deviation,

$$\lambda = \frac{1}{n} 2 s \sin \frac{\varphi}{2}$$

In the fifth method collimator and observing telescope are kept at a fixed angle with each other and the grating is turned. In this case if φ is the angle of deviation and θ the angle between the telescopes

$$\lambda = \frac{1}{n} 2 s \sin \varphi \cos \frac{\theta}{2}$$

These methods are general and the choice between them is simply a question of the convenient application of the apparatus at hand. Probably the first and the second methods are the most generally useful, while the third is the most objectionable. The method of minimum deviation slightly increases the experimental difficulties, but often improves the definition of the gratings and is capable of giving very exact results. The last method is applicable only when the spectrometer is so rigid as to ensure the permanence of the angle between the telescopes. When this condition is fulfilled, however, the method is very valuable, since it reduces the moving mass to a minimum and allows the method of repetition to be readily used.

In the present research for the work with glass gratings the second method was selected as best suited to the arrangement of the spectrometer. This was a very good instrument by Meyerstein. The circle is 32^{cm} in diameter, divided on silver to $6'$ and reading by two microscopes directly to $2''$ and by estimation easily to within $1''$. The collimating and observing telescopes are of 4^{cm} clear aperture and about 35^{cm} focal length, well corrected and firmly supported.

For the second part of the work, with speculum metal

gratings, it was desirable to use gratings of the largest size practicable, far larger than could be used on the above described instrument, both by reason of the small aperture of the telescope and the inability of the grating holder to carry the requisite mass steadily. This part of the work was, therefore, carried out on a very large instrument, designed by Prof. Rowland especially for using gratings of the largest sizes as yet ruled. This instrument has virtually fixed telescopes, solidly clamped, with a small lateral range of adjustment, to a T-shaped casting bedded in cement which in turn forms the top of a large brick pier resting on a stone slab.

The telescopes are of 16·4^{cm} clear aperture, and about 2·5 meters focal length and the objectives are of excellent quality. Each telescope is fastened to an arm of the T, which has a total length of over 2 meters, and bears, at the extremity of the shaft the spectrometer proper. This is an instrument by Schmidt and Haensch, having a circle 32^{cm} in diameter divided to 6′ and, as in the other spectrometer, reading by two microscopes directly to 2″ and by estimation to less than half that amount. The original central platform had been removed and replaced by a grating holder large enough to carry if necessary a 6 inch grating. Such an apparatus limits one, of course, to the fifth method, but so rigid is the whole affair that experience soon showed that the angle between the telescopes did not change by any appreciable amount. The circle, however, was not finely enough graduated, nor were the microscopes of sufficient power to derive the fullest benefit from the size of the telescopes; over and over again has the line in the spectrum appeared slightly displaced from the crosshairs, when no difference whatever could be detected in the micrometer readings. However, there was gained the great advantage of using gratings of a decimeter in length, giving spectra of great brilliancy and superb definition, and which could be measured with vastly greater exactness than is possible with the small gratings generally employed.

Gratings.

Four gratings have been used in my experiments—two of glass and two of speculum metal. The former are probably the best of the very few glass gratings that have been ruled on Prof. Rowland's engine. They are ruled on plane sextant mirrors of rather hard glass.

Grating I, contains 12,100 spaces in a length of very nearly thirty millimeters, the lines being nineteen millimeters long. It was ruled in Jan., 1884, at a temperature of 6°·7 C. gives spectra of excellent definition, quite free from ghosts or false lines, and having almost exactly the same focus on both sides of the normal.

Grating II has 8600 spaces with almost exactly the same length and breadth as I, is free from ghosts and false lines and like I, is very smoothly ruled, though it is somewhat inferior to I in the matter of regularity. The definition is excellent and the spectra alike in focus on both sides of the normal. It was ruled in Nov., 1884 at 11°·6 C.

Gratings III and IV are on speculum metal. The plates are five inches square and five-eighths of an inch thick, and were worked plane with especial care. The ruled surface is of the same size in each, four inches long by two inches length of lines.

Grating III was ruled in April, 1885, at a very nearly constant temperature of 10° C. It contains 29,000 spaces, having very nearly the same grating space as II. It is a phenomenal grating both in its superb definition and extraordinary regularity of ruling, and was selected from a large number because of its very unusual perfection. The focus of the spectra on each side of the normal is the same and the ruling is flawless.

Grating IV was ruled on the new dividing engine just completed by Prof. Rowland, and was one of the first large ones completed. While the new engine has even now not received the finishing touches, it has turned out a few gratings of remarkable excellence. One of these is IV, which was ruled in Dec., 1887, at a constant temperature of 17°·2 C. It contains 40,000 spaces within the same dimensions as III, is equal to it in definition, and but very little inferior in regularity of ruling. It has very nearly the same focus on both sides of the normal, and the ruling is wonderfully even and perfect.

It should be noted that these four gratings are widely diverse, being ruled at different temperatures and under different conditions. I and II were ruled to widely diverse grating spaces on different parts of the screw, III was on speculum metal and with more than six times the ruled surface of I or II, and finally IV was ruled to a new grating space on a new dividing engine. These differences may not favor close agreement in the experimental results, but they certainly serve to eliminate anything like systematic errors due to the gratings.

The above gives a general view of the gratings employed, but some further details will be mentioned in the second part of this paper in connection with the determination of the grating spaces.

On the Standards of Length.

Very many of the discrepancies in the determinations of absolute wave-lengths are the direct result of uncertainty in the standard of length employed. The cases of Ångström and van der Willigen have been already alluded to, and the same

source of error is common to all other determinations. It seems, therefore, desirable to give at some length the various comparisons on which the wave-length as given by my experiments is based. Reserving for the present the actual measurement of the gratings, which is a comparatively simple matter, I will therefore discuss the standards directly employed, their relations to the Metre des Archives as found by various comparisons, and finally the changes which have taken place in those relations since they were first determined.

The standards with which the gratings have been directly compared are two double decimeters on speculum metal, designated respectively S^a_1 and S^a_2. They were graduated and compared by Prof. W. A. Rogers in 1885. The bar S_1 is 23^{cm} long and bears near its edge the double decimeter S^a_1, subdivided to centimeters. The defining lines are less than 1 μ in width and beautifully sharp and distinct. S_2 is 27^{cm} long and is graduated in the same way, with lines of the same width. Both standards are of the same speculum metal, and are of very nearly the same mass, while the surfaces and graduation leave little to be desired. The coefficient of expansion of these bars was very thoroughly investigated by Prof. Rogers and was found to be,

$$17{\cdot}946\,\mu \text{ per meter per degree C.}$$

The absolute lengths of S^a_1 and S^a_2 depend on long series of comparisons with Prof. Rogers's bronze yard and meter R_2 and steel copies thereof. Upon the relation existing between R_2 and the Metre des Archives depends then the absolute value assigned to the wave-length of light, since the close agreement of the various series of comparisons executed by Prof. Rogers between R_2 and the speculum metal standards show that no sensible uncertainty exists in the relations between them.

The yard and meter R_2 is of the alloy known as Bailey's metal, this being the material of the Imperial Yard and many other standards. The graduations are upon platinum iridium plugs, the polished faces of which are in the plane of one surface of the bar when supported at its neutral points. The relation of the meter R_2 to the Metres des Archives rests on a very large number of comparisons made with two entirely independent secondary standards; the copper meter designated T, and the brass yard and meter designated C. S. A full account of these comparisons is contained in vol. xviii of the Proceedings of the American Academy of Arts and Sciences.

The meter T is on platinum plugs in a pure copper bar and was traced and compared by M. Tresca in 1880, from the Conservatoire line meter No. 19, the relation of which to the Metre des Archives was very exactly known.

The yard and meter C. S. has its graduations on silver plugs in a brass bar. The yard was compared directly with the Imperial Yard in 1880, and the standard was then sent to Breteuil where it was compared with the International Meter by Dr. Pernet.

There were thus two completely independent sources from which the relation of R_2 to the Metre des Archives could be obtained. The results derived by very elaborate comparisons with each of these were as follows:

$$\left.\begin{array}{l}\text{From T} \quad R_2 - A_0 = +\ 1{\cdot}5\mu \\ \text{From C.S.} \ R_2 - A_0 = +\ 1{\cdot}1\mu\end{array}\right\} \text{ at } 16°{\cdot}67 \text{ C.}$$

Where A_0 is the Metre des Archives. In addition to the very close agreement of the above, further evidence was obtained by deriving the relation between the yard and meter from R_2, the yard R_2 having been exactly determined by comparisons with C. S. and with "Bronze 11," one of the primary copies of the Imperial Yard, which had been recompared with that standard in 1878.

From the comparisons of S_1 and S_2 made in 1885 the following value of those standards were deduced:

$$S^a{}_1 + 0{\cdot}98\mu = \tfrac{1}{5}A_0, \text{ and}$$
$$S^a{}_2 + 0{\cdot}2\mu = \tfrac{1}{5}A_0. \quad \text{Hence}$$
$$S^a{}_2 = S^a{}_1 + 0{\cdot}78\mu, \text{ and for the first decimeters}$$

were found the relations:

$$\left.\begin{array}{l}Dm_1S^a{}_1 + 0{\cdot}05\mu = \frac{1}{10}A_0 \\ Dm_1S^a{}_2 - 0{\cdot}01\mu = \frac{1}{10}A_0 \\ Dm_1S^a{}_2 = Dm_1S^a{}_1 + 0{\cdot}06\mu\end{array}\right\} \text{ Whence,}$$

On these equations were based the results embodied in my former paper. In the latter part of May, 1887, these standards were very carefully compared with each other and with a speculum metal bar graduated by Prof. Rowland, as I desired to take one or more of the standards to Berlin during the summer in order to get a comparison with the standard used by Müller and Kempf.

The results of this examination were of a somewhat startling character, as follows:

$$S^a{}_2 = S^a{}_1 + 1{\cdot}2\mu, \text{ direct}$$
$$S^a{}_2 = S^a{}_1 + 1{\cdot}1\mu, \text{ through the Rowland bar}$$

designated R_B. Also,

$$Dm_1S^a{}_2 = Dm_1S^a{}_1 + 1{\cdot}7\mu, \text{ through } R_B$$

In 1885 Rogers had found for the relation between the two decimeters of each bar:

$$Dm_2S^a{}_1 = Dm_1S^a{}_1 - 0{\cdot}56\mu$$
$$Dm_1S^a{}_2 = Dm_2S^a{}_2 + 0{\cdot}46\mu$$

I now found for the same quantities:

$$\begin{aligned} Dm_2S^a_1 &= Dm_1S^a_1 + 0{\cdot}64\mu, \text{ direct,} \\ Dm_2S^a_1 &= Dm_1S^a_1 + 0{\cdot}60\mu, \text{ from } R_B \\ Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}60\mu, \text{ direct} \\ Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}65\mu, \text{ from } R_B \end{aligned}$$

All these relations being for 16°·67 C.

The standard S^a_2 was taken to Berlin during the summer and through the kindness of Dr. Nieberding, Director of the Normal Aichungs Commission, I was enabled to have it compared with R_{78} the standard meter to which the wave length measurements of Müller and Kempf, and Kurlbaum had been referred. From this comparison was derived the relation:

$$S^a_2 - 1{\cdot}68\mu\ (\pm 0{\cdot}15\mu) = \tfrac{1}{5}A_0$$

On returning to Baltimore the first step was to redetermine the length of S^a_2. A series of comparisons was therefore instituted between it and the steel yard and meter A_4, the relation of which to R_2 was accurately known, A_4 having been traced and determined by Prof. Rogers and furnished by him to the Johns Hopkins University. Only half of this standard is subdivided to decimeters but a series of comparisons with the various pairs of decimeters gave the relation,

$$S^a_2 + 1{\cdot}3\mu = \tfrac{1}{5}A_0$$

This result taken together with the relations found between S^a_1 and S^a_2 made it tolerably clear that a change had taken place in the speculum metal standards, and to obtain a further confirmation Prof. Rogers kindly consented to give them a rigid examination and again compare them with all attainable accuracy to R_2. His results for S^a_2 were as follows:

$$\begin{aligned} Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}70\mu \\ S^a_2 + 1{\cdot}0\mu &= \tfrac{1}{5}A_0 \end{aligned}$$

There is no escape from the conclusion, therefore, that the speculum metal bars S_1 and S_2 have changed both in absolute length and the relative lengths of their parts. Here are two bars of the same shape, mass, material, and constant of expansion. Each had the relation between its halves determined in the early part of 1885. Two years later these relations are found to have changed by at least 1μ, and an independent determination by the original observer confirms this result in the most unequivocal way. Further, the original observer recompares one of these standards with the standard from which it was originally determined and finds a change of 1μ.

It should be borne in mind that with the comparator used by me in this work, 1μ is completely outside of any possible errors of observation. The microscope used was especially

made for micrometric work and has a power of two hundred and fifty diameters, while one division of the micrometer equals $0{\cdot}28\mu$. The average error of a single comparison between two decimeters is rarely greater than $0{\cdot}1\mu$, while the temperature of the observing vault can be kept for several days constant within $0°{\cdot}5$ C. and during a day's observations usually remained constant within half that amount. The bars under comparison were side by side, symmetrically placed with reference to the illumination, and were at temperatures very near to $16°{\cdot}67$, at which they were standard.

The facts then concerning the speculum metal bars are these: In about two and a half years S^a_2 has shortened by very nearly $1{\cdot}0\mu$ and S^a_1 by a little over that amount. In S^a_2 this change has taken place exclusively in the last decimeter and in S^a_1 it has been confined to the first decimeter.

The apparent slight increase in $Dm_1S^a_2$ and $Dm_2S^a_1$ I do not regard as beyond the effect of the experimental errors. The changes in the lengths of the subdivisions of these standards are very curious and some explanation may be offered by the fact that the bars were cast in a nearly vertical position and annealed in sawdust, a method hardly sufficient for a material so strongly crystalline as speculum metal. I think, however, one is justified in drawing the conclusion that speculum metal, so tempting on account of its beautiful surface and the exquisite sharpness of the graduations drawn upon it, is a material thoroughly unsuitable for standards of length by reason of its tendency to change with time. I have thus entered into somewhat minute details in the case of these bars, because the whole question of changes in standards of length is in a somewhat unsettled state, and it seems desirable to put on record this case, which has been investigated with more than ordinary care by both Prof. Rogers and myself, and in which the changes found have taken place within a comparatively short time.

It is quite well-known that in 1855 this question was raised by Mr. Sheepshanks, then engaged in constructing the new British standards. Discrepancies amounting sometimes to 2 or 3μ appeared in his measurements, but after a considerable amount of study, these differences appeared to be too irregular to be fairly ascribable to actual changes. Slight variations of temperature, especially when the standards compared were of different materials, the lagging of the real temperatures of the bars behind the thermometer indications, and particularly the effect of coarse and sometimes unsymmetrical defining lines, are perhaps enough to account for the observation.

The work, however, done on the U. S. bar "Bronze 11," as reported in the report of the Coast Survey for 1877, seems to show genuine change in that standard.

A long series of comparisons with the Imperial Yard and its copies in 1878, showed systematically a shortening relative to the Imperial Yard of over 4μ. Although further measurements have tended to somewhat lessen this discrepancy it seems to be sufficient, considering the fact that "No. 11" and the Imperial Yard are of the same shape, material and mass, and were compared on the same apparatus as during the original comparisons in 1857, and at nearly the standard temperature, to establish the fact of a real change. While 3 or 4μ is absolutely a small quantity, its systematic appearance under conditions almost identical with those of the original measurement can hardly be ascribed to experimental errors. The other cases cited in the above mentioned paper tend to confirm this conclusion.

The gradual and sometimes very irregular changes that are known to take place in both the bulbs and stems of thermometers, would lead one to expect that glass standards of length would be liable to similar changes, though probably in far less amount. It was, therefore, with special interest that I examined glass Decimeters III and IV belonging to the Coast Survey, and used by Peirce in his wave-length measurements. These scales are on plate glass, of the same dimensions, and having coefficients of expansion not widely different. A series of comparisons made at a nearly constant temperature of 16°·5 C. gave the direct relation

$$\text{III} = \text{IV} + 2{\cdot}1\mu$$

While the same relation deduced from Peirce's direct comparison by applying the coefficients of expansion assigned by him, is

$$\text{III} = \text{IV} + 1{\cdot}3\mu.$$

The defining lines on both standards are fine and sharp, and unless Peirce's coefficients are grossly in error, the evidence of change between 1879 and 1887 is very strong indeed.

Having now the exact present relation of S^a_2 to the original standard R_2, it remained only to investigate the difference between this result and the length of S^a_2 as deduced from the Berlin comparisons. I have been unable to obtain the details concerning R_{78}, the standard used in these comparisons, but it was determined by comparison with the standard meter of the International Bureau. The comparisons of S^a_2 with R_{78} were carefully made by two observers, and it is probable that the result represents the relation between these standards with considerable exactness. It should, however, be borne in mind that the microscopes had power of only 50 diameters, and that the bars in question are of very different material and mass, thus giving a chance for small errors due to varying temperature.

It is possible, however, to check this result by referring S^a_2 to the Berlin platinum standard through the medium of the Coast Survey meter "No. 49." This latter standard was compared in 1876 with meter 1605 and directly with the platinum meter. The details are given in Prof. Foerster's report contained in the report of the Coast Survey for 1876. The result of the direct comparison was

$$Pl - \text{“}49\text{”} = +24{\cdot}4\mu.$$

But now Prof. Rogers has compared R_2 with "49," obtaining in terms of the assumed length of R_2

$$\text{“}49\text{”} = A - 19{\cdot}3\mu,$$

the assumed value of R_2 was,

$$R_2 = A + 1{\cdot}3\mu.$$

Hence we have,

$$R_2 - \text{“}49\text{”} = 20{\cdot}6\mu,$$

from which follows,

$$Pl - R_2 = 3{\cdot}8\mu.$$

If now the equation between Pl and the Metre des Archives established by direct comparison in 1860 be correct:

$$A_0 - Pl = -3{\cdot}01\mu.$$

And therefore,

$$R_2 - A_0 = -0{\cdot}8\mu,$$

a result which is in close accordance with those derived from the Conservatoire meter and Type I of the International Bureau by means of the Standards T. and C. S.

In my final determination of wave-length, I have used the mean value of S^a_2 as derived by the foregoing methods. Collecting equations,

$$S^a_2 + 0{\cdot}96\mu = \tfrac{1}{6}\, A_0 \quad \text{From T.}$$
$$S^a_2 + 1{\cdot}04\mu = \tfrac{1}{6}\, A_0 \quad \text{“ C. S.}$$
$$S^a_2 + 1{\cdot}40\mu = \tfrac{1}{6}\, A_0 \quad \text{“ “49.”}$$
$$S^a_2 - 1{\cdot}68 = \tfrac{1}{6}\, A_0 \quad \text{“ } R_{78}.$$

Giving to the equations derived from C. S. and R_{78} twice the weight of the others, we have finally,

$$S^a_2 + 0{\cdot}27\mu = \tfrac{1}{6}\, A_0.$$

I have given the relations derived from C. S. and R_{78} double weight because these standards have been compared directly with the standard of the International Bureau, which now, probably, should be regarded as the ultimate standard of reference. Especially is this true, since it is rumored, apparently not without foundation, that the Metre des Archives is, at present, for some unassigned reason, undesirable as a direct standard of reference.

It is unfortunate that there is not more general uniformity in the material, shape and mass of standards of length. Difference in these particulars are fruitful sources of error in comparisons, and when one adds to this the trouble arising from

bad defining lines and imperfect focus, the wonder is that the results are as good as they usually are. It is hard to say what material is least liable to changes, but it is quite certain that substances of crystalline structure, and alloys of which the physical properties are largely dependent on a nearly definite composition, should be avoided. Probably pure platinum, silver, and copper, annealed with the utmost care, and kept for some years before final graduation, are less likely to change than any other material which we know. For short standards, possibly bars of native copper, prepared with as few strains as possible, would give the closest possible approximation to a material which has arrived at a permanent state.

Physical Laboratory, Johns Hopkins University, Feb. 22, 1886.

[To be continued.]

ART. XXIII.—*History of the changes in the Mt. Loa Craters;* by JAMES D. DANA. Part I. KILAUEA. Continuation of the Summary and Conclusions. (With Plates IV and V).

[Continued from xxxiii, 433; xxxiv, 81, 349; xxxv, 15, 181, 1888.]

B. *The Ascensive Action in the Conduit lavas.*

1. *Evidence.*—The evidence in favor of an uplifting action by the ascensive force has been presented in volumes xxxiv, pp. 83, 89, and xxxv, p. 25. It is briefly as follows:

(1) The observations in 1846 by Mr. Chester Lyman demonstrate that in six years the lower pit of 1840, averaging 10,000 feet by 2,500 in its diameters and nearly 400 feet in depth, had gradually become obliterated, and chiefly through an uplift of the floor; for the floor bore on its surface the talus of lava blocks that had fallen from the walls. Overflows had done part of the work, but "subterranean force," as Mr. Lyman concluded, the larger part. Mr. Coan, who was with Mr. Lyman at the time, appreciated the evidence, and later described the lifting as "not uniform in all parts; as sometimes taking place here and there abruptly; but as producing nearly uniform results, except a greater rise toward Halema'uma'u."

(2) In 1868, Mr. Brigham gave further evidence as to the Lyman ridge by the representation of what remained of it in 1865 (xxxiv, 89, and xxxv, 24), on his valuable map, though not, as his memoir shows, understanding its origin. Besides this, the painting of the crater of about the same date (1864 or earlier) by Mr. Perry afforded confirmatory proof as to its position and extent at that time (xxxv, 25).

(3) In 1848, Mr. Coan observed that a cone of broken lava that had formed within the Halema'uma'u basin, was lifted by "subterranean action," as he argued, because only slight addi-

tions were made to its outside by ejections. It continued to rise bodily until it was as high as the near walls of Kilauea (xxxiv, 86). Between 1880 and 1882, another debris cone began in the basin of Halema'uma'u which, as he describes, rose in like manner without additions to its summit, and finally became 200 feet or more high; this cone continued to exist until the eruption of 1886.

The subterranean force appealed to was plainly force arising in some way from the lavas beneath. Mr. Coan, in his letters to me, supposed that the lifting was produced by the injection of the lavas of the conduit into open spaces between the solid layers below.

(4) Again, in the summer of 1886, three months after the eruption of that year, the debris from the falling walls of Halema'uma'u were *seen* to be made into a cone occupying a large part of the interior of the basin; and from August onward, it was apparent that the cone so made was slowly rising, though having little outside additions; in October, its top was on a level with the rim of the basin; in January, 200 feet higher, so as nearly to overtop the southeastern Kilauea walls. It was early apparent to visitors at the crater that the elevation was through action below; and soon the conclusion was general, among observers, that the cone, as expressed in the words of Mr. Dodge, of January 14, 1887, was "rising slowly as though floating on the surface of the new lava-lake."* The mean rate of elevation, according to the heights given, was about two feet a day.†

The ascensive force was thus proved to be great, and its effects to have fundamental significance.

2. *Method of Action.*—It is a question whether, in the lift of the floor of the great crater in 1823, 1832, 1840, 1868, the lavas of the lava-conduit acted by direct thrust, or through injections into spaces between the layers of solidified lava beneath it.‡ The facts favor strongly the former of these views. In the first place, the lateral thrust in the upper lavas of a conduit is necessarily feeble; for the conduit there, or near by, opens to the surface. Then secondly, it is quite certain that the breadth of the Kilauea conduit at top has been, at the times of these up-

* This Journal, xxxiv, 70.

† I was informed, when at Honolulu, by Mr. Parmelee, of that place, that in August of 1886, he made observations on the rate of change of level, by sighting from the Volcano House verandah over a post 100 yards in front of the house, and marking the change of the line of sight on a pillar of the verandah. His observations were made between the 19th and 21st of the month, on the first day of the rise, according to his calculated result, was 16 feet; on the second, 17; and on the third 8 feet. These numbers are large. They were not verified by observations near the cone. They at least prove progress in the elevation.

‡ The latter is the explanation adopted by Mr. Brigham in his paper of July, 1887, xxxiv, 19.

lifts of the floor, large enough to act somewhat equably against the floor. Thirdly, since the floor kept its even surface as it fell at the great eruption of 1840, it must have followed down, as already urged, the subsiding lavas (page 213). The flotation method, or that by direct thrust, seems therefore to be the right one. It is the obvious explanation of the lifting of the debris cones of Halema'uma'u.

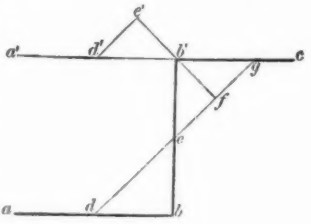
Kilauea affords, as has been indicated, facts illustrating the details connected with the lifting movement.

3. *Fault planes of the up-and-down movements about the pit.*—(1) The down-plunge of 1823, 1832, and 1840 left, for the most part, vertical walls bounding the "lower pit" so made. There is evidence that these were fault-walls, that is, planes of fracture with a vertical displacement along them equal to their height, or about 400 feet in 1840 and 600 or 800 feet in 1823. In the reverse movement, that is, the rise after the down-plunge of 1840, the old floor was carried up along the same fault-planes. The rate of rise, as shown on page 16, was 70 to 130 feet a year, which is to be divided between (*a*) overflows (*b*), vesiculation if this had any effect, and (*c*) ascensive force apart from vesiculation.

Further: these vertical fault-planes of 1840, and others subordinate to them along the border regions, appear to have determined the chief places of eruption, that is, of lava-lakes, cones, ovens and opened fissures in Kilauea *during the next thirty years*. They were plainly the occasion of the wonderful girt of fires, four miles long and half a mile wide, which was three times repeated after the year 1846 before the eruption of 1868 (in 1855, 1863, and 1866), while the interior plateau suffered relatively little change from erupting forces, and in some parts was growing ohelo bushes and ferns.

The position of the "canal" in Kilauea in 1846 described by Mr. Lyman and also by Mr. Coan, as extending around the crater, bounded by the outline of the old black ledge and the Lyman ridge of lava-blocks, and which became gradually filled by inflowing lavas and debris, has here its explanation. The circumferential fault-planes of the pit of 1840 coincided with the face of the lower wall or precipice. The debris which fell from the wall necessarily fell to the floor beyond the plane and there began the making of the talus. Through the fall of the face of the wall, the wall, and thereby the limit of the black ledges, retreated, and as the elevation of the floor went on, an interval was left between the talus and the limit of the black ledge, and along this interval lay the "canal." The annexed figure will serve to illustrate the point, notwithstanding the assumptions made in it. Let bb' be the wall of the lower pit, 400 feet high, and the course of the fault-plane;

ab the floor of the pit; *b'c*, the surface of the black ledge. Let now the falls from the wall above *e* make the talus *deb* with a slope of 45°, causing thereby the wall (and limit of the black ledge) to retreat to *g*. If the floor be now lifted 400 feet, to the position *a'b'*, the debris of the talus *deb* would make an elevation at top equal to *d'e'b'*, besides filling up *ef'b'*, ($ef'b' = d'e'b' = \frac{1}{2}deb$); the interval *b'f'g* would represent the canal, and *d'e'b'*, 100 feet high, the ridge.



If the floor were raised 50 feet higher, the ridge would be lowered, say 25 feet, owing to material that would slip down into the canal; and consequently, the height of the ridge above the floor over the center of the crater would then be 25 feet less than before, while 25 feet more than it was above the black ledge. If no talus had been formed at the foot of the wall, an uplift of the floor of 500 feet would have made a precipice of 100 feet fronting toward the black ledge, the falls from which would have produced a steep talus. These are two conditions in the different parts of the ridge mentioned in Mr. Lyman's paper.

(2) *Fault-planes about Halema'uma'u.*—In Halema'uma'u at the eruption of 1886, there was a circumferential fault plane; this seems to be implied in the fact that the return of lava was mostly through vents toward the walls, little coming up at the center; and the fact that even a year and a half afterward, the action was greater outside of the cone than at its center. At the discharge, the debris from the tumbling walls fell beyond the fault-plane and made an accumulation of blocks, like the talus of the lower pit of 1840, and this, as Mr. Dodge's description shows and the photographs illustrate, was the material that became the cone as the lifting went forward.

(3) *Conclusion.*—By the above facts, it is proved that the conduit lavas of the volcano not only keep up the supply of heat, and carry on, by means of the vapors, projectile action and vesiculation, but also that they furnish power for lifting, in a quiet, unperceived way, the floors of craters with whatever is upon them, and thus raising the level of volcanic activity; and that this goes forward as part of the *ordinary* operations of the crater. The action has long been recognized as a means of supplying heat and lavas, but not as a mechanical agent to the extent here indicated. The force at work in making the Gilbert laccoliths must be the same, and Mr. Gilbert, in his

report on the Henry Mountains, gave the first intelligible idea of its power.

But there is nothing in the action that leads us to suppose that it can, under any probable conditions, make jets or fountains of lavas, or work in blow-hole style. Each jet over a lake, and each large jet in a lava-fountain, has its local projectile cause beneath the projected column of lava, and cannot be produced by any general upthrust movement in the great conduit. The imperceptibly slow uplift and fountain-making are incompatible effects. There seems to be, therefore, no foundation for the comparison of the lava fountains to the projectile effect in an "artesian boring made to a stratum of molten rock which had only been awaiting an opportunity to overflow."*

The *source of the ascensive movement* I have stated to be undetermined. It is most commonly referred to the pressure of the earth's crust on the lava reservoir beneath, arising from subsidence in the earth's crust from secular refrigeration. Another explanation appeals to vapors from the deep source of the lavas. The possibility of some addition to the force through ascending vapors is referred to on page 195 of this volume.

C. *Effects of Heat.*

1. *From change of temperature.*—Contractional effects from cooling, that is fractures and changes of level, should be common in the crater; for each stream has passed from a temperature of 2000° F. or more to 70° or 80° F. and the upper surface of a stream rapidly so. Besides ordinary shallow fractures, the cause produces also an imperfectly columnar structure in the cooled lava-stream below the upper foot. The cracks in the floor often expose quite good basaltic columns even when the thickness of the layer is hardly a dozen feet.

There should be also larger effects in the Kilauea region arising from change of temperature between periods of great and little activity, or from periodical variations in the heat below, and changes of level in the lava of the conduit. But we have no special facts to report in illustration, although there are cracks innumerable in view that probably have this source.

2. *The dissolving action of the liquid lavas.*

(1.) The *refusion of the crust* over the surface of a lava-lake by the liquid lavas is—as the history has shown—one of the common occurrences in Halema'uma'u and other lava-lakes.

* Mr. W. L. Green, Vestiges of the Molten Globe, pp. 168, 272. Mr. Green's examples are taken from action in the summit crater, and when speaking of that crater this point will be again considered.

The intervals of cooling and refusion vary in length from a few seconds to an hour and longer. The crust of a lava-lake is often only the thin, easily fusible glassy scum, but thicker crusts also yielded to the heat.

In the case of rapid transitions, the cooling and refusion may be due to the loss of heat by the expansion in the process of vesiculation; and if the vesiculation takes place intermittently for any reason (as from oscillating movement in the lava column, or other condition) it would occasion the alternations between the fused and crusted state. But for the crustings at longer intervals deeper movements may be concerned, and more study is needed before they are fully understood.

(2.) *The disappearance of floating islands* is another effect of heat and chiefly of refusion. For in some cases the islands have after a while—a year or more—disappeared.

(3.) *The destruction of debris-cones* in Halema'uma'u is dependent on undermining by the active lavas and vapors beneath; and, in one case, the destruction was probably completed before a period of eruption (xxxiv, 88).

The debris-cone, 1500 to 2000 feet broad at base, which now occupies the center of the Halema'uma'u basin is already in process of dissolution. It made no increase in height during the summer of 1887, but, instead, rather lost ground through the changes going on. This fact was obvious in August last; for the east wall, a single continuous ridge in October, 1886, had become divided into two ridges, and dense vapors rose from the interval between, with sounds of splashing lavas that were evidence of an active lava-lake below A photograph taken in October, 1886, copied on Plate IV, shows the condition of this side of the cone at that time when it had reached its maximum height; and Plate V, from a photograph taken nearly a year later, in September last (a month after I left the crater), exhibits the condition above described. Both views were taken looking westward, and the foreground in each is the bottom of Halema'uma'u on the east side of the cone. In Plate IV dense vapors may be seen issuing from a large aperture near its middle, and other vapors from a lower place to the right (north). In Plate V, the vapors escape copiously *all the way between* these two places and far southward, showing the subdivision nearly completed. A photograph taken in the spring of 1887 exhibits an intermediate stage in the process of division. A letter of Jan. 2 of the current year, from Mr. J. H. Maby, proprietor of the Volcano House, says that the bottom of the Halema'uma'u basin on the east side (that shown in the plates) has risen much and is now nearly on a level with the upper surface between it and "New Lake" and a lava-lake has opened in it, so that the fires and the overflows are visible from the

Volcano House, and "to all appearances, the lavas will soon be running into New Lake."

The description given by Professor Van Slyke of the cone as seen by him in July, 1886, gives particulars as to the steam-holes in and beneath the cone, and the blowing-cone work, which began this work of destruction and prepared the way for the subdivision. He states that he ascended the cone to a perpendicular well, which opened through its side by a hole "30 or 40 feet wide and 60 to 75 feet long," and looking down to the bottom 100 feet below, saw the lavas rising and falling in jets from a small vent. In another well of like depth, 20 to 30 feet in diameter, there was a cone and "lava boiling with intense violence" (xxxiii, 96).

This destructive work brings the cone to its end either before, or during, a period of eruption; and a floating island may be the last phase before its disappearance.

(4.) *Opening of new lava lakes.*—With the intensifying of the fires of the crater there has often been, as the history shows, an opening of lakes over the interior of the crater, and especially along the borders of Kilauea, or the region of the black ledge. Such facts signify, as I have explained, that the broad underlying conduit of Kilauea, which is like a great reservoir of lavas beneath the pit, reaches at such a time up to the surface, not only in the Halema'uma'u basin through the great conduit, but also in minor lakes through secondary conduits. It is a query whether this has ever been brought about by new sources of vapor starting in the underlying reservoir, as a consequence of subterranean conditions; whether hot vapors from such a source have not forced a way through to the surface in consequence of their own dissolving and fusing heat and that of the lavas, and thus have made a new lake;—as ascending air from the bottom of an ice-covered pond makes a hole through the covering of ice. But such lakes, as remarked on a preceding page, are generally begun over fissures, and it may be that fissures, under the general increased activity, are all that are needed for the result.

(5.) *Extending the limits of the conduit by fusion.*—Another suggestion comes from the fusing power of the Halema'uma'u lavas. If these lavas can slowly, even at their surface, fuse stoney lavas, what is the extent of the fusing power at depths below where there is greater heat? An increase in the heat from a subterranean cause would necessarily widen the limits of the conduit. It is a question whether an extended subterranean bed of liquid lava, thick enough to remain permanently liquid in spite of cooling agencies about it, can occupy its place without fusing and incorporating with itself any solid lavas directly underneath it, if such there be? A

great lava-conduit, therefore, has probably its varying phases, like the fires at the surface, and includes extremes in breadth or enlargement as well as in contraction. The widest part should not be at the summit unless the cooling agencies are *less* effective, or the heat-making causes more so, there than elsewhere.

3. *The metamorphic action of the heat.*—Metamorphic action also may be part of the quiet work of the volcano. The lava-column has its enclosing rocks, and at temperatures varying from that just below fusion to that of the outside rocks; and vapors must be active in the hot regions. The throat of the conduit may well be, therefore, a region of recrystallizations, of the making of geodes, or lining fractures with crystals, out of whatever material was at hand, and differing somewhat according to the temperature. The effects of such metamorphism are exhibited, beyond question, in the various mineral crystallizations in the ejected masses of Vesuvius. They are found also at Kilauea and will be mentioned beyond.

D. *Hydrostatic and other Gravitational Pressure.*

1. The hydrostatic pressure of the column of liquid basalt is 2·8–2·9 times that of water, supposing the lavas while in fusion to be mainly in the glassy condition. This pressure was early recognized by Lyell as one of the possible causes of rupture in volcanoes. The cause may have its effects in a quiet way over the bottom of Kilauea, since the lavas often stand in the lakes at a height of 50 to 100 feet above the floor outside of the surrounding cone; but no facts yet observed can be positively referred to it.

2. Again, there may be *undermining*s and therefore *subsidences* in the ordinary course of Kilauea changes, through discharges following small fractures. But such effects are not at present distinguishable from those of other modes of origin.

Having thus reviewed the ordinary operations of the crater, that is, those carried forward between times of eruptions in the way of preparation for an eruption, the next enquiry is, What is needed to produce a great eruption of Kilauea? The power of the rising vapors and that of the ascensive conduit-lavas, the two chief sources of ordinary activity, appear to be too feeble for any such result. Can eruptions take place without any increase of their activity within the crater beyond what has been described? If so, how?

Before discussing this subject, the history of the summit crater, Mokuaweoweo, may be first reviewed, as its facts afford important illustrations of the eruptive methods.

[To be continued.]

ART. XXIV.—*The Electromotive Force of Magnetization;** by EDWARD L. NICHOLS and WILLIAM S. FRANKLIN.

AT the Ann Arbor meeting of the American Association for the Advancement of Science, we described some singular modifications in the relation of iron to acids which occur when the reaction takes place within the magnetic field. The present paper deals with the behavior of iron when that metal acts as one electrode in a voltaic circuit, and is at the same time subjected to magnetization.

A galvanometer placed in a circuit consisting of two electrodes of iron, metallically connected on the one hand, and dipping, on the other, into a cell containing any liquid capable of dissolving them, will indicate the existence of a current whenever the reaction between the metal and the liquid differs in character or rapidity at the two terminals. There are always at work a number of causes of such inequality of action, and the electro-motive force between iron poles in any liquid which attacks them freely is not inconsiderable. It amounts as a rule to several thousandths of a volt and even when special precautions have been taken to secure homogeneity in the elements of the circuit, a sensitive galvanometer will not fail to show the existence of a current. If one of the terminals be placed within a magnetic field, new differences of potential will be developed, both from the magnetization of the iron and from the change in the chemical relations between the metal within the field and the liquid. This electromotive force we have proposed to call *the electro-motive force of magnetization.*

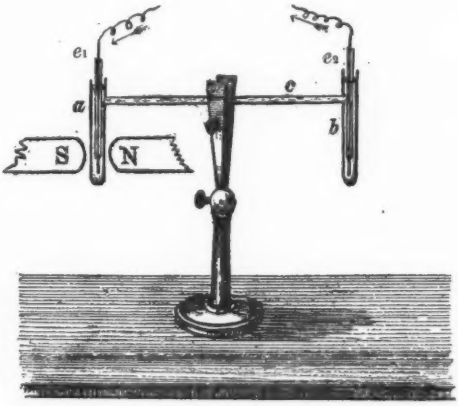
With the exception of two papers by Dr. Theodor Gross† of Berlin, which came to our notice too late to enable us to take advantage of their valuable contents in our investigation, we know of no observations of the effect of magnetization upon the voltaic behavior of iron. Dr Gross's research deals chiefly with the electro-motive force due to the magnetization of the iron, and touches only incidentally upon the nature of the currents produced when one of a pair of iron electrodes has its electro-chemical relations to the solution modified by being placed within the magnetic field. It is with the latter phase of the subject, principally, that our experiments have to do.

* Paper read at the New York meeting of the American Association for the Advancement of Science, August 11, 1887.

† Th. Gross; Ueber eine neue Entstehungsweise galvanischer Ströme durch Magnetismus: Sitzungsberichte der Wiener Academie, vol. xcii, 1885.

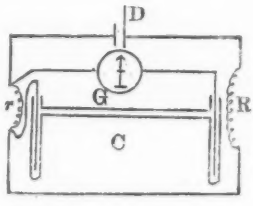
The first form of cell, which we used, consisted of two glass tubes, *a* and *b* (figure 1), about 1^{cm} in diameter and 10^{cm} long. These were closed at the lower end and were connected by a

1.



narrower glass tube (*c*), about 50^{cm} in length. The electrodes, e_1 and e_2, consisting of soft-iron wire, were inserted through the open ends of *a* and *b*. They were exposed to the liquid for about 1^{cm} at their lower ends. When this apparatus was filled with a liquid capable of dissolving iron, it formed a single cell, one terminal of which could be placed between the poles of an electro-magnet, while the other was well outside of the field. When the free ends of the wires, e_1 and e_2, were connected through a sensitive galvanometer, it was found that, although the terminals were taken from the same piece of wire, and were immersed in the same liquid, a measurable current was always flowing in the circuit. The electro-motive force was constant neither in amount nor in direction. In many liquids it changed but slowly, however, and could be balanced by means of a variable counter-electro-motive force introduced into the circuit. For this purpose a Daniell's cell was placed in circuit with two variable resistances, R and *r* (figure 2). The cell with iron electrodes was shunted around *r*, and the ratio R/*r* was so adjusted that the current in the shunt circuit, due to the Daniell cell, was just sufficient to reduce the galvanometer deflection to zero. The

2.



galvanometer could then be sensitized to any desired extent, but the fluctuations in the electro-motive force of the iron cell were such that the balance was never more than momentarily maintained, and the galvanometer drifted continually.

In very weak acids and in solutions of $FeSO_4$, $FeCl_2$, NH_4Cl, and similar salts, these fluctuations were not such as to preclude the possibility of making measurements, but in concentrated acids they were for the most part so rapid and irregular as to put galvanometer readings out of the question. In nitric acid, of considerable strength, these fluctuations were so remarkable as to deserve special mention. The electro motive force, amounting to a considerable fraction of a volt, changed sign continually, carrying the spot of light across the galvanometer scale, to and fro, with great rapidity. The frequent and irregular oscillations continued with undiminished violence until the electrodes were entirely dissolved or the acid nearly neutralized. Upon first closing the circuit one of the iron terminals would be slightly more active than its fellow. The tendency of the less active electrode would then be to protect the other from the attack of the acid, rendering it temporarily passive, as a piece of platinum would do under the same circumstances. The passive terminal would then react in like manner upon the first and electro-motive force would be reversed again and again until the electrodes were consumed.

In those cases in which the fluctuations were not such as to make the attempt at compensation ineffectual, we were able to make measurements of the initial electro-motive force of the cell and of the changes in electro-motive force caused by the action of the magnet.

One of the iron terminals was placed between the poles of a large electro-magnet. To obviate any direct effect of the magnet upon the galvanometer needle, the galvanometer was set up in a room several hundred feet distant from that in which the former instrument was located. The "iron" cell having been connected with the wires leading to the galvanometer room, the initial electro-motive force was balanced by the method already described, and the galvanometer was brought to the desired degree of sensitiveness by means of a governing magnet. One observer then proceeded to make galvanometer readings at intervals of fifteen seconds, while another magnetized and demagnetized the electro-magnet every two or three minutes, reversing the magnetizing current each time. The electro-magnet in question has been described in a previous paper.*

Like most large instruments of the kind, it required several seconds after the circuit had been closed to attain its full

* This Journal, vol. xxxi, p. 272.

strength; and it retained considerable residual magnetism when the circuit was broken. By the following very simple device, however, the residual magnetism was almost entirely destroyed. A reversing switch of Poggendorff's pattern and an ordinary telegraph key were placed in series in the magnetizing circuit. While the magnet was in function, a piece of soft iron wire about 1^{cm} long was suspended by magnetic attraction from the underside of one of the pole-pieces. The wire served as an indicator of the magnetic condition of the poles. Upon breaking circuit with the key the residual magnetism was sufficient to hold it in position. When, however, the current was first reversed by means of the Poggendorff switch, and then broken at the instant when the magnet was passing through the condition of neutrality, the proper moment being indicated by the dropping of the suspended wire, the magnet was left thoroughly demagnetized. The interval of time between reversal of the current and neutrality was about two seconds.

After each series of readings, the galvanometer was calibrated, the resistance of the iron cell was measured and the strength of the magnetic field was estimated by a modification of Rowland's method. The instrument used in most of these measurements was Edelmann's form of the Wiedemann galvanometer, read with telescope and scale. For some experiments in which a high degree of sensitiveness was necessary a Thomson reflecting galvanometer of 2500 ohms resistance was used.

It was found possible by this method, excepting when the fluctuations in the initial electro-motive force of the cell were very marked, to detect changes amounting to much less than ·00001 volts.

We experimented with a variety of reagents, including nitric, hydrochloric and sulphuric acids; ferrous sulphate, ferrous chloride, and ammonium chloride, in aqueous solutions, and finally, sulphuric acid, to which potassium bichromate had been added, and hydrochloric acid containing potassium chlorate. In every case there was unmistakable evidence of the development of a permanent electro-motive force due to the influence of the magnet. The smallest effect, ·000008 volts, was observed with terminals in concentrated nitric acid, the iron being passive—the largest effect in those solutions in which rapid oxidization took place. In a solution consisting of dilute sulphuric acid containing potassium bichromate, the electro-motive force of magnetization amounted to ·039 volts. In the same acid, the concentrated sulphuric acid of commerce diluted with ten parts of water, without the addition of the potassium bichromate, it was only ·0005 volts. Concentrated hydrochloric acid (sp. gr. 1·1768), gave ·003 volts, the same acid, diluted with four parts

of water, only ·00002. When potassium chlorate was added to the dilute acid, the effect due to the magnet became very marked, amounting certainly to several hundredths of a volt; but the fluctuations in the initial electro-motive force were such as to make readings impossible. In nitric acid diluted with nine parts of water the effect was also very large, but it was so masked by the initial fluctuations described in a previous paragraph, that no quantitative determinations were secured. The strength of field during these experiments was about 10,000 H.

In the hope of eliminating these fluctuations in the initial electro motive force, two modifications of our apparatus were made. In the first, it was so arranged that a current of the fresh solution passed through both arms of the cell and the products of the reaction were carried away from the neighborhood of the terminals almost as soon as formed. In the second modification, terminals were prepared the surface of which consisted of pure iron, electrolytically deposited. When these prepared terminals were used, the fluctuations were somewhat less marked than when the original surface of the iron wire was exposed, but the adoption of these two modifications led to no new results. A more important modification consisted in the substitution of platinum or copper for the iron terminal outside of the field. These metals, being unaffected by the magnet, could be placed in close proximity to the magnetized terminal: the internal resistance of the cell was thereby greatly diminished and its form simplified. The iron-copper and iron-platinum cells were placed between the poles of the electro-magnet, and the investigation consisted in determining the electro-motive force before and after the magnet had been made active. The most satisfactory results were obtained with a cell patterned after the Daniell battery—a two-fluid cell in which copper immersed in sulphate of copper was separated from the iron pole by a porous diaphragm, the iron being submerged in a solution of ferrous sulphate or of ferrous chloride. A cell of this description, in which a neutral solution of ferrous sulphate surrounded the iron, and which possessed an initial electro-motive force of ·6072 volts, increased to ·6361 volts when placed within the field. Similar results were obtained with other solutions.

In the various forms of apparatus already described the currents due to magnetic action did not always flow in the same direction. The iron terminal within the field would sometimes act as zinc toward the unmagnetized electrode, sometimes as platinum. To determine the law governing the direction of the currents due to the electromotive force of magnetization we tried the following experiments. The terminals of iron wire used in our original apparatus were supplanted by cylin-

ders of soft Norway iron 1^{cm} long and 4^{mm} in diameter. These were placed horizontally in the solution and were attached to the end of copper wires. The wire was in each case thoroughly insulated from the liquid, and the iron bar itself was protected by a coating of wax with the exception of a single portion of its surface, which to the extent of a few square millimeters was exposed to the action of the liquid. Under these conditions, the direction of the electro-motive force developed between the terminal within the field and a similar one outside was found to depend upon the portion of the bar exposed and the position of the latter with reference to the lines of force. Whenever the exposed surface was in the neighborhood of an induced pole within the soft iron electrode it became in its relations to iron outside of the field, as zinc to platinum. Whenever on the contrary the exposed surface was situated in a neutral portion of the bar, it became as platinum in its relations to unmagnetized iron. When platinum, carbon or copper was substituted for the unmagnetized electrode the electro-motive force of the cell thus formed was increased by magnetization, in the case in which a pole of the iron terminal was exposed to the liquid and diminished by magnetization when the surface acted upon lay in the middle of the bar. A reversal of direction in the current flowing between such a bar of iron in the field, one end of the bar being exposed to action, and an unmagnetized iron terminal, could be produced by turning the former in the field. When the axis of the bar was parallel to the lines of force and it was accordingly magnetized longitudinally, it acted as a zinc pole, the current flowing from its surface through the cell to the unmagnetized electrode. When turned through 90° upon an axis perpendicular to the line joining the poles of the electro-magnet, the bar became magnetized transversely and the direction of the current was reversed.

Between bars lying with their axes parallel to the lines of force, the end of one and the middle of the other of which was exposed, the effect was more marked than between either of them and a piece of unmagnetized iron; the bar with exposed pole acting as zinc, that exposed in the middle as platinum.

After having determined the conditions which govern the direction of the current, we turned our attention to the relation between the strength of the magnetic field and the electro-motive force which it is capable of producing. The cell selected for this work was an iron-platinum element, containing a solution of potassium bichromate in dilute sulphuric acid. In this liquid the electro-motive force of magnetization was so marked that when the cell was placed between the pole pieces of the electro-magnet the influence of the residual magnetism of the latter upon its electro-motive force could easily be de-

tected. Measurements were made in fields varying in intensity between 2000 H., and 20,000 H. The results are given in the following table. They show the manner in which the effect in question increases with the strength of the field.

TABLE.

Influence of the Strength of Field upon the Electro-motive Force of Magnetization.

Strength of field.	E. M. F. in volts.
2000 H.	·0008 volts.
3600	.0045
5040	·0208
7770	·0386
8400	·0424
12750	·0487
16300	·0510
19700	·0680

We had noticed in the course of our experiments that a layer of the more or less magnetic solution of the salts of iron, produced by the reaction, always gathered around the induced poles of the electrode within the field. In this way a two-fluid battery was formed between the iron within the field and that outside, whenever the surface nearest the poles of the magnetized electrode was exposed. The terminal within the field was thus surrounded by a concentrated solution of its own salts, and was in a measure protected against the direct attack of the acid. In the case however in which a neutral portion of the electrode within the field was exposed, the products of the reaction were continually withdrawn by magnetic attraction towards the pole-pieces, and the surface was left more open to attack than the opposing electrode outside of the field.

For the purpose of ascertaining whether this arrangement of the solution in the field would tend to produce the effects which have been described, measurements were made of a variety of batteries in which iron formed one electrode. The results were such as to make it evident that the influence of the magnet could, in part at least, be thus explained. An iron-carbon cell, the liquid being nitric acid diluted with one part of water, was found to have an E. M. F. of ·88 volts. When the acid was placed in a porous cup, containing the carbon pole, and the iron was submerged in weak sulphuric acid (1 : 10), the E. M. F. rose to 1·33 volts. The same metals in dilute sulphuric acid containing potassium bichromate gave 1·05 volts which was increased to 1·32 by placing the carbon and bichromate solution in a porous cup and the iron in dilute sulphuric acid. A cell with iron and platinum, in a solution consisting of 200^{cc} of strong hydrochloric acid, 200^{cc} of water and 20^{grms} of potassium chlorate, gave 1·17 volts. When converted into

a two-fluid battery, the iron submerged in weak sulphuric acid, the platinum in the above solution, the E. M. F. became 1·39 volts. When the iron in the last case was submerged in dilute hydrochloric acid the result was nearly the same, the E. M. F. being 1·41 volts. In sulphuric acid containing potassium permanganate the same metals gave 1·44 volts, which rose to 1·60 volts when the platinum and solution were placed in a porous cup and the iron was dipped in sulphuric acid containing no oxidizing agent. Iron and platinum in ferrous chloride showed only ·74 volts, but a two-fluid battery with iron—dilute hydrochloric acid—ferrous chloride—platinum gave 1·07.

In all these cells the electro-motive force obtained by the solution of iron with ferric reaction was smaller than when a ferrous reaction occurred. The application of this fact in the explanation of the electro-motive force of magnetization is very manifest. When the *poles* of an electrode within the magnetic field are exposed to action, the gathering of the salts of iron around the exposed surface tends to bring about a change from *ferric* to *ferrous* reaction and to *increase* the electro-motive force. A corresponding *decrease* follows when a neutral surface is exposed within the field. The extent to which the electro-motive force of a cell in which a ferric reaction is taking place may be reduced by briskly stirring the solution and exposing the surface of the iron to the fresh acid, thus doing mechanically what is done magnetically when the reaction occurs, at a neutral surface, within the field, was shown by the following experiment. A one-fluid cell, consisting of iron and platinum in nitric acid diluted with four parts of water, had an electro-motive force of 1·07 volts. Stirring reduced it to ·95 volts. When left undisturbed it immediately regained its former intensity.

The electro-motive force developed between the poles of one iron electrode placed within the magnetic field and the neutral parts of a similar electrode in the same cell, will also exist between the poles and intermediate portions of a single piece of iron. Consequently there will always be local action between different portions of the surface of iron exposed to chemical action within the field, the currents passing through the liquid from the regions nearest the induced poles.

It is doubtless to this local voltaic action, which has its source in the electro-motive force of magnetization, that the various phenomena, described in our papers on *the chemical behavior of iron in the magnetic field*,* and on *the destruction of the passivity of iron by magnetization*,† are to be ascribed.

* This Journal, vol. xxxi, p. 272. † Ibid., vol. xxxiv, p. 419, Dec., 1887.

ART. XXV.—*Notes on certain rare Copper Minerals from Utah;* by W. F. HILLEBRAND and H. S. WASHINGTON.

[Read before the Colorado Scientific Society, Jan. 2d, 1888.]

SOME time since analyses and partial descriptions of several rare copper minerals, from the American Eagle Mine, Tintic District, Utah, were published * by one of us. These minerals had been found by Mr. Richard Pearce in ore shipments from that mine to the Boston & Colorado Smelting Works, near Denver, Colorado. Later, in shipments from the neighboring Mammoth mine, in the same district, Mr. Pearce discovered a second series of minerals of similar character, most of the species, however, being distinct from those of the former occurrence. In recent papers † he has given the results of his examinations and enumerated the following species: enargite, olivenite, conichalcite, clinoclasite, brochantite, pharmacosiderite, tyrolite (?), erinite, chalcophyllite, malachite, azurite, and one or two others of doubtful identity, of most of which "enargite is the mother mineral."

In order that this interesting series, in part new to America, might receive fuller study than he was able to devote to it, Mr. Pearce with the assistance of Mr. Whitman Cross kindly selected a set of specimens for examination in the laboratory of the U. S. Geological Survey at Washington. The chemical work of this paper was there carried out by one ‡ of us, while the crystallographical and optical study was undertaken by the other § at New Haven under the guidance of Prof. E. S. Dana. The results of our work, both chemical and physical, failed to meet all the hopes induced by a first view of the material at disposal, although this was the best that could be found. They are of sufficient interest, however, to make public, especially in view of the meager state of our knowledge regarding a majority of the species herein mentioned.

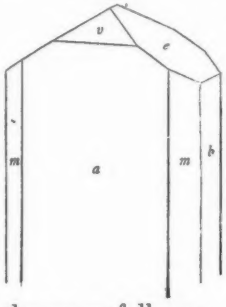
1. OLIVENITE.

This mineral occurs well crystallized; its habit is prismatic and tabular parallel to a (100, $\bar{\imath}\text{-}\bar{\imath}$) and the crystals are, as usual, very simple as shown in the figure. The planes b (010, $\bar{\imath}\text{-}\bar{\imath}$) and v (101, $\bar{\imath}\text{-}\bar{\imath}$) as a rule are either absent or very small. Measurements were made for the purpose of obtaining a more exact axial ratio than we have at present, the old values of Phillips dating back to 1823.

* Proc. Colorado Sci. Soc., i, 112, and Bull. U. S. Geol. Survey, No. 20, p. 83.
† Proc. Colorado Sci. Soc., ii, 134, 150.
‡ W. F. Hillebrand. § H. S. Washington.

Upon examination and measurement with a Fuess horizontal goniometer it was found that $e \wedge e'$ $(011 \wedge 0\bar{1}1)$ was the only angle sufficiently accurate for the purpose, a and m being a little rough and uneven. The angle mentioned furnished a good value for $\dot{c}$, but to obtain the value for $\breve{a}$, use had to be made of a specimen of olivenite from the American Eagle Mine (No. 5684 in the Yale University collection). This olivenite was acicular in habit, the prism m $(110,\dot{i})$ predominating. From these crystals good measurements were obtained of $m \wedge m'''$ $(110 \wedge 1\bar{1}0)$ and a satisfactory axial ratio deduced. The measured angles are as follows:

Fig. 1.



$$e \wedge e',\ 011 \wedge 0\bar{1}1 = 67°51'$$
$$m \wedge m''',\ 110 \wedge 1\bar{1}0 = 86°26'$$

From these angles we obtain the following axial ratio,—

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}93961 : 1 : 0{\cdot}672606$$

The measurements above differ considerably from the fundamental angles of Phillips, which are,

$$e \wedge e',\ 011 \wedge 0\bar{1}1 = 69°10' \text{ and } m \wedge m''',\ 110 \wedge 1\bar{1}0 = 87°30'$$

giving the axial ratio,

$$\breve{a} : b : \dot{c} = 0{\cdot}9573 : 1 : 0{\cdot}6894$$

Measurements were made with the view of determining whether the species is really orthorhombic or not. The following are the angles obtained—

$$a \wedge e,\ 100 \wedge 011 = 89°4',\ a' \wedge e,\ \bar{1}00 \wedge 011 = 89°59'$$
$$a \wedge e',\ 100 \wedge 0\bar{1}1 = 89°9',\ a' \wedge e',\ \bar{1}00 \wedge 0\bar{1}1 = 90°1'$$

It is seen that the front angles are in each case a trifle less than the rear angles, but not much reliance can be placed on these results, owing to the poor surface of both a (100) and a' $(\bar{1}00)$.

Under the microscope the tabular crystals showed parallel extinction and a slight pleochroism, the vibrations $\parallel \dot{c}$ being pale olive green, while those $\parallel \bar{b}$ were of a brownish yellow, with the absorption $b > c$.

The mineral was not analyzed because of the small quantity available and because its identity was otherwise clearly established.

2. Erinite.

Erinite occurs as a dark green crystalline lining of cavities, associated with and generally upon enargite, azurite, barite, or

clinoclasite. Crystals of olivenite are frequently scattered over its surface, which shows often a somewhat satiny sheen due to minute crystal facets. Hardness 4·5. Sp. gr. undetermined. Because of its intimate association with azurite and olivenite it was very difficult to obtain pure material for analysis. Sample I contained 3·90 per cent of insoluble matter, not included in the analysis. Sample II was composed of a small lot of vitreous crusts, the only ones of the kind observed, which had been collected before shipment of the specimens and were thought to be erinite by Mr. Pearce, whose partial analyses of material similar to sample I are added, for comparison, under III.

	I.	II.	III.	
	Hillebrand.		Pearce.	
			a.	*b.*
CuO	57·67*	57·51	56·56	57·43
ZnO	1·06	0·59	----	----
CaO	0·32	0·51	0·43	----
MgO	tr.	tr.	----	----
As_2O_5	33·53	31·91	32·07	32·54
P_2O_5	0·10	----	----	----
H_2O	7·22	9·15	6·86	7·67
Fe_2O_3	0·14	0·20	0·85	----
SO_3	----	- --	tr.	----
	100·04	99·87	96·77	97·64

Analyses I and II, and presumably those of Pearce, show the composition of air-dried powder. Sample I lost 0·67 per cent H_2O over sulphuric acid and a total of 0·78 per cent at 100° C. At 280° C. the total loss was 1·14 per cent, leaving 6·08 per cent firmly combined. Sample II lost 2·06 per cent over sulphuric acid and a total of 3·22 per cent at 2·80° C., leaving 5·93 per cent firmly combined. The molecular ratios, including all the water, are:

	CuO (CaO, ZnO)		As_2O_5 (P_2O_5)		H_2O
I.	5·08	:	1·00	:	2·74
II.	5·34	:	1·00	:	3·66
III. (mean)	5·13	:	1·00	:	2·87

If the weakly combined water be excluded from both I and II the ratio is brought considerably nearer to that derived from Turner's approximative analysis,† i. e., 5 : 1 : 2.

It is uncertain whether Turner's sample was air-dried or heated to 100° C.

3. Tyrolite. (?)

Regarding the identity of this species some doubt exists, as the analytical results obtained do not agree with those given by

* Mean of 57·61 and 57·74.

† Edin. Journ. Sci., ix, 95, 1828. Phil. Mag., iv, 154, 1828.

von Kobell* and Church†. In general appearance it seems to resemble tyrolite. It occurs in thin scales on quartz, but more often in radiating scaly masses, somewhat like the pyrophyllite from Graves Mt., Ga. It has a bright apple-green color, sometimes with a tinge of blue; a somewhat pearly luster; a hardness of 2·5 (1·5–2 for tyrolite in the text books), and perfect cleavage. Under the microscope it showed little or no pleochroism and extinction parallel and perpendicular to the radial line. In convergent light the cleavage flake showed the ordinary biaxial figure with the dispersion $\rho > \upsilon$. Its double refraction is negative, the acute bisectrix being perpendicular to the cleavage face, and coinciding with the crystallographic $\dot{c}$. The obtuse bisectrix lies parallel to the radial direction of the crystal, but whether it corresponds with $\breve{a}$ or $\bar{b}$ cannot be determined. It was unfortunate that a crystallographic investigation was impossible, as our knowledge of tyrolite in this respect is of the most meager description.

On heating it flies into fine fragments, which by gentle tapping of the tube collect into spongy masses. The mineral melts in the flame of a Bunsen burner.

The Sp. grav. of sample I (containing 2·25 per cent of insoluble gangue) was 3·27 at 20½ C. From sample II, which was the purest and best crystallized to be found, 1·25 per cent of gangue has been deducted.

	I.			II.	III.	
			Hillebrand. Mean.		Pearce.	
	a.	*b.*				
CuO	45·20	45·23	45·22	46·38	42·60	
ZnO	----	0·04	0·04	tr.	0·97	($Fe_2O_3Al_2O_3$)
CaO	6·86	6·82	6·84	6·69	9·10	
MgO	0·05	----	0·05	0·04	----	
As_2O_5	28·84	28·73	28·78	26 22	27·87	
P_2O_5	tr.	----	tr.	tr.	----	
H_2O	17·26	----	17·26	17·57	16·23	
SO_3	?	?	?	2 27	2·45	
	98·21		98·19	99·17	99·22	

SO_3 was unfortunately not tested for in I. It may however reasonably be assumed to be present in about the same amount as in II, and if it be considered to be present as gypsum ($CaSO_4, 2H_2O$) the following molecular ratios are obtained.

	CuO (CaO)		As_2O_5		H_2O					
I.	5·00	:	0·94	:	6·80	or	11	:	2·07	: 14·96
II.	5·00	:	0·84	:	6·81	or	11	:	1·85	: 14·98
III.	5·00	:	0·90	:	6·29	or	11	:	1·98	: 13·84

It appears herefrom that the As_2O_5 is somewhat less and the H_2O much less than required to satisfy the formula $5CuO, As_2O_5, 9H_2O$, derived from von Kobell's (l. c.) analysis on the

* Pogg. Ann., xviii, 253. † Journ. Chem. Soc., [2], xi, 108.

supposition that the $CaCO_3$ found by him and later by Frenzel* and Church (l. c.) is not an essential constituent of tyrolite.

It is improbable that more than a very small quantity, if any, chalcophyllite was mixed with the material analyzed under I and II, although both appeared on some of the specimens marked tyrolite received from Mr. Pearce, and are not always easy to distinguish. In any mixture of tyrolite and chalcophyllite the water found must exceed its percentage in the former mineral. This is here not the case, whence it is to be inferred either that the present mineral is not tyrolite or that the older analyses do not represent its true composition.

A large portion of the water is very loosely combined. Of that in analysis I, 4·69 per cent escaped at 100° C., the most of it over sulphuric acid; and in analysis II, 4·15 per cent was removed by sulphuric acid, and further 0·91 per cent escaped at 100° C., making a total of 5·06 per cent. These amounts subtracted from the total percentage found leave 12·57 and 12·51 per cent respectively, or about five molecules (assuming five molecules, (CuO(CaO)). At 280° C. the loss on sample II was 10·34 per cent, in which is presumably included the water of the gypsum supposed to be present, leaving three molecules firmly combined. Church (l. c) likewise noticed a great loss of water in vacuo and at 100° C., but assumed that it was hygroscopic water included between the plates of the mineral. The second of his analyses with data for calculating the percentage composition is as follows:

Substance	0·4585	CuO	50·06
H_2O in vacuo	0·024	As_2O_5	29·29
H_2O at 100°	0·011	H_2O	[8·73]
$CaCO_3$	0·0505	$CaCO_3$	11·92
CuO	0·212		
$Mg_2P_2O_7$	0·205		100·00

whence he deduces the formula $5CuO, As_2O_5, 4H_2O$. Assuming that $Mg_2P_2O_7$ is an error for $Mg_2As_2O_7$, or for As_2S_3, in which latter form it appears that arsenic was usually estimated by him in minerals of a similar character, it is impossible to deduce the above given percentage for As_2O_5. But considering the latter correct, and including the water lost in vacuo and at 100°, the composition is:

CuO	46·24
As_2O_5	27·05
H_2O	15·70
$CaCO_3$	11·01
	100·00

which furnishes the molecular ratio $CuO : As_2O_5 : H_2O$ as 5·00 : 1·01 : 7·43, not greatly differing from those derived from analyses I and II above.

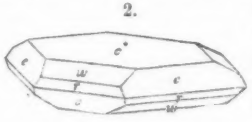
* Naumann-Zirkel, Elemente der Mineralogie, p. 540.

4. Chalcophyllite.

This mineral occurs in the form of small hexagonal plates arranged in rosettes, differing from the radial arrangement of the supposed tyrolite. It showed the same bright apple-green color, pearly luster, and perfect basal cleavage. An optical examination proved it to be uniaxial with negative double refraction.

These crystals showed several planes replacing the edges, and measurements were made of them as far as possible. The angles did not agree very closely owing to the imperfection of all the surfaces, but they were sufficiently exact to prove the presence of r (10$\bar{1}$1, R), e (01$\bar{1}$2, $-\frac{1}{2}R$), and two other rhombohedrons, new to the species, having the symbols w (10$\bar{1}$6, $-\frac{1}{6}R$), and d (01$\bar{1}$3, $-\frac{1}{3}R$). The figure shows the habit of the crystals, but with d absent, this plane being only observed in one instance. The very rough angles obtained are given below:

2.



	Observed.	Calculated.
$c \wedge r$, 0001 $\wedge$ 10$\bar{1}$1	71° 27′	71° 16′
$c \wedge w$, 0001 $\wedge$ 10$\bar{1}$6	26° 10′	26° 10′ 20″
$c \wedge e$, 0001 $\wedge$ 01$\bar{1}$2	56° 51′	55° 51′ 10″
$c \wedge d$, 0001 $\wedge$ 01$\bar{1}$3	41° 50′	44° 30′ 30″

The above observed angles are the means of several measurements which vary among themselves from one to three degrees. The fair agreement in the first two results therefore is merely accidental, and no value can be attached to these measurements, which are inserted because the measurements of this species are extremely few.

The mineral was not analyzed for want of sufficient material. On heating, it decrepitated as violently as the last mentioned mineral, and in the flame of the burner fused, though not with the same readiness.

5. Clinoclasite.

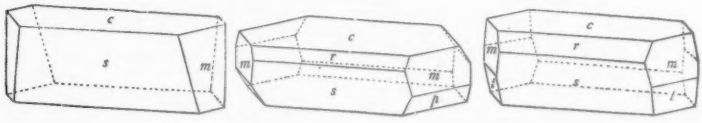
The clinoclasite occurs in two distinct habits, one distinctly crystallized and the other in barrel shaped or globular forms. It is of a dark bluish green color, almost black by reflected light, bright green by transmitted light. Streak and powder bluish green. Specific gravity at 19° C., 4·38. (4·36 Pearce.) Hardness 2·5–3.

At first sight these crystals seemed to be very promising and likely to afford good fundamental measurements for the species. But on further examination they did not come up to our expectations, c (001, O) and s ($\bar{3}$02, $\frac{3}{2}$-i) being the only two planes giving even fairly good measurements. m (110, I),

r (101, –1-i), t ($\bar{1}11$, 1) and p ($\bar{1}13$, $\frac{1}{3}$), the other planes observed, were all dull or rounded, and only capable of giving angles accurate enough to identify the forms. Of the planes above, t and p are new to the species. Most of the crystals were apparently made up of two or more individuals in nearly parallel position but inclined slightly in the zone c/b. A measurement in one case gave the angle 4° 10′, but as it is not the result of twinning, this angle of course is not constant and only shows the very slight inclination of the individual crystals. A consequence of this method of growth will be described later.

The crystals were all simple; fig. 3, or a combination of that with r, being the most usual. Occasionally the lower half of m

3. 4. 5.



is replaced by t, as shown in fig. 5, giving the angle 13° 20′ (calculated 13° 17′) for $m \wedge t$. The new plane p ($\bar{1}13$) was observed in several crystals and is shown in fig. 4. The following angles were obtained for it:

	Observed.	Calculated.
$c \wedge p$, $001 \wedge \bar{1}13$	61° 6′	61° 26′ 30″
$s \wedge p$, $\bar{3}02 \wedge \bar{1}13$	50° 14′	51° 19′ 10″
$p \wedge p'$, $\bar{1}13 \wedge \bar{1}\bar{1}3$	82°	85° 48′

The angles are merely approximate, but sufficient to establish the form. The crystals are for the most part elongated in the direction of the b axis, with a length of from 2 to 3^{mm}, and show easy cleavage parallel to c.

The other type of clinoclasite is interesting, as showing the consequence of the nearly parallel growth of the crystals mentioned above. In some of the specimens the crystals are grouped about the b axis, with c exposed. They are inclined a trifle in the zone c/b and also in the zone a/b, thus rounding off the group in two directions, but decidedly more in the latter zone, forming, with the elongation in the direction of b, distinctly barrel-shaped forms. Occasionally the curvature in the zone c/b is carried still further, producing globular forms. In all cases c forms the outer surface and the crystals are closely crowded together, producing a bright and coarsely rough surface.

The material analyzed consisted of the globular masses mentioned above, and was probably not as pure as the crystals and barrel-shaped forms. A trifling amount of insoluble matter (0·05 per cent) has been deducted. For comparison Mr. Pearce's partial analyses are also quoted.

	I. Hillebrand.			II. Pearce.		Theoretical Composition.
	a.	*b.*	Mean.	*a.*	*b.*	
CuO	62·34	62·54	62·44	61·68	61·22	62·65
ZnO	0·06	0·04	0·05	----	----	----
As_2O_5	29·59	29·60	29·59	29·36	28·85	30·25
P_2O_5	0·05	0·05*	0·05	----	----	----
H_2O	7·73	7·72	7·72	7·31	7·27	7·10
Fe_2O_3	0·12	0·12	0·12	----	----	----
SiO_2	0·06	0·06*	0·06	----	----	----
	99·95	100·13	100·03	98·35	97·34	100·00

These results reveal nothing worthy of remark except that the water, as in most earlier analyses, is found uniformly higher than that required by the formula $6CuO, As_2O_5, 3H_2O$, or $Cu_3[AsO_4]_2+3Cu[OH]_2$.

6. Mixite. (?)

On some specimens of ore, but apparently not in close association with the other minerals mentioned, was a mineral occurring in delicate tufts of silky needles of a whitish to pale greenish color as described by Mr. Pearce (l. c., p. 151, under the title "New Mineral"). It was impossible to procure enough of the needles free from an underlying non-crystallized greenish coating of cavities for a satisfactory analysis. A good deal of the latter was necessarily included in the sample tested, but qualitative tests showed that both needles and coatings contained the same constituents. It is hardly to be doubted that both have the same centesimal composition.

	I. Hillebrand.			II.
	a	*b*	Mean.	Pearce.
CuO	43·89	43·88	43·89	50·50
ZnO	2·79	2·62	2·70	----
CaO	0·26	0·26	0·26	3·19
Bi_2O_3	11·14	11·22	11·18	----
As_2O_5	27·78	28·79	28·79†	27·50
P_2O_5	0·06	----	0·06	----
H_2O	11·04	11·04	11·04	12.55
SiO_2	0·36	0·48	0·42	----
Fe_2O_3	0·97	----	0·97	----
	98·29		99·31	93·74

That an error as to the CuO occurs in Pearce's analysis is beyond question. The above results agree fairly well with Schrauf's analysis of mixite,‡ which contained 43·21 CuO, 13·07 Bi_2O_3, 30·45 As_2O_5, and 11·07 H_2O, besides a little CaO and FeO, but the form of this mineral as given by Schrauf differs from that of the present one, and its color is given as

* Assumed the same as in *a*.

† The higher value was undoubtedly nearer the truth than the lower.

‡ Zeit. f. Kryst., iv, 277.

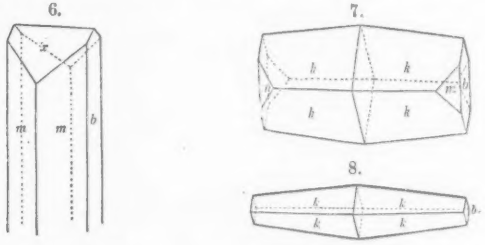
emerald to bluish green. Schrauf's number for the sp. grav (2·66) is unquestionably much too low. That of the material now analyzed was 3·79 at 23½° C. When treated with dilute nitric acid it becomes at once covered with the brilliant white coating of bismuth arseniate so characteristic of mixite. The latter mineral is stated to belong to the monoclinic or the triclinic system, while the observations of Mr. Whitman Cross would indicate that the present one can belong to neither of those systems. He says:* "The needles are very slender, with a length of more than 1^{mm} in some cases, by 0·5^{mm}. They are deeply striated vertically, and the crystal system could not be determined, although the extinction in polarized light makes reference to the tetragonal, the hexagonal, or the rhombic system necessary. The index of refraction is high. Pleochroism distinct, the colors observed being for the thicker crystals, *a* (and *b*) sea green, *c* sky blue."

7. Pharmacosiderite.

No analyses were made for want of sufficient material.

8. Brochantite.

This hydrous sulphate of copper occurs in two distinct types in the specimens examined. The first, or ordinary brochantite, is of a prismatic habit as is shown in fig 6. The crystals are dark green and transparent, but do not give good measurements, owing to the imperfection of the surface. The cleavage parallel to $\bar{b}$ (010, $i\text{-}\bar{i}$) is perfect. The measured angle of $m \wedge \bar{b}$, $110 \wedge 010 = 51° 46'$, is only approximate, and differs con-



siderably from Miller, who gives 52° 5′, and Schrauf, who gives 52°.

* Proc. Colorado Sci. Soc., ii, 153.

The second type is like warringtonite from Cornwall, described by Maskelyne.* This variety was suspected by Mr. Pearce (loc. cit., p. 135). It is of a light green color and has a curved double wedge-shaped habit. The forms observed are shown in figs. 7 and 8. The crystals were poor for measuring, all the planes, with the exception of *b*, being curved to a great degree. The crystals were none of them more than 2 or 3mm long, with the relative proportions of the figures. They were implanted by *b*; *m*, in fig. 7, was identified with certainty, the angle for $b \wedge m$ being 52° approximately. The plane lettered *k* was very much curved in all cases and its symbol, consequently, is not known with exactness. It corresponds in its angles very roughly, it is true, to the *k*, 12.1.4, of Schrauf; some of the angles obtained from these crystals and the corresponding ones of Schrauf's warringtonite being given here:

	Washington.	Schrauf.
$b \wedge k$, 010 ∧ 12.1.4 =	80°–82°	86° 43′
$m \wedge k$, 110 ∧ 12.1.4 =	45°	43° 11′
$k \wedge k'$, 12.1.4 : 12.1.$\bar{4}$ =	75°–80°	

In most of the crystals of this type *b* was undulating parallel to *c*.

Want of material forbade an analysis of this mineral, but blowpipe tests and the crystallographic examination establish its identity beyond doubt.

ART. XXVI.—*The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature;* by CHAS. D. WALCOTT, of the U. S. Geological Survey. With Plate III.

(Continued from page 242.)

GEOLOGY OF THE TACONIC AREA AS KNOWN TO DR. EMMONS.

(1). The strata referred to the "Taconic System;" (2). The stratigraphic position of the "Taconic System."

Dr. Emmons began the study of the Taconic area in Berkshire County, Mass., and from there extended his investigations, to the north, into Bennington County, Vt., and to the west, into Washington and Rensselaer counties, N. Y.† In 1842,‡

* Ch. News, x, 263, 1864. Phil. Mag., IV, xxix, 475.

† "My first business is to sketch a picture of the oldest of the sediments, as they are exhibited in a series which collectively constitute the Taconic System and as it is developed in the Taconic ranges of Berkshire and the adjacent country immediately north and south." (Am. Geol., pt. 2, p. 5, 1856).

‡ Geol. N. Y., pt. 2, p. 144, 1842.

he proposed the Taconic System, with the statement that it was composed of five different rocks, as follows:

"1. A coarse granular limestone of various colors which I have denominated *Stockbridge limestone*," etc.

"2. *Granular quartz* rock, generally fine-grained, in firm, tough, crystalline masses of a brown color, but sometimes white, granular and friable."

"3. *Slate*, which for distinction I have denominated *Magnesian slate*," etc.

"4. *Sparry limestone*, generally known as the sparry lime-rock."

"5. A slate, which I have named *Taconic Slate*, and which is found at the western base of the Taconic range. It lies adjacent to the Lorraine or Hudson River shales, some varieties of which it resembles," etc.

A section is given on page 145, fig. 46, to show that the "Taconic System" embraced all the strata between the gneiss on the east and the "shales of the Champlain group" on the west. The latter are represented as unconformably superjacent to the "Taconic slate."

His second memoir appeared in 1844* as a pamphlet, published in advance of vol. i, of the Agriculture of New York, in which, in 1847, the subject matter was reprinted without change. The changes from the stratigraphic scheme of 1842 consist in placing the granular quartz at the base of the system, with the Stockbridge limestone conformably resting upon it. A theoretical section† is given to show the relation of the various formations. The crystalline gneiss is represented with (1), the Granular Quartz or brown sandstone resting upon it; then, in turn (2), the Stockbridge limestone; (3), Magnesian slate; (4), Sparry limestone; (5), Roofing slate; (6), coarse brecciated bed; (7), Taconic slate, and (8), Black slate. On the following page, the section shown by fig. 7 represents these beds as all having a high and uniform dip to the eastward,‡ and with the Hudson river shales (9), unconformably superjacent to the Taconic slate (8).

When speaking of the lithologic characters of the system, Dr. Emmons says: "Taking one broad view of the whole system, it may be described as consisting of fine and coarse slates,

* Agric. N. Y., vol. i, pp. 45-112, 1847. The pamphlet of 1844 is very rare, as few copies were issued, and I shall make all references to its contents as reprinted in the volume of 1847, combining the dates as 1844–'47.

† Loc. cit., p. 62, fig. 6.

‡ This is corrected for the "Lower Taconic" rocks in the Section published in 1856 (Am. Geol., vol. i, pt. 2, p. 19), but all the strata of the "Upper Taconic" are considered superior to the Stockbridge limestone.

with subordinate beds of chert, fine and coarse limestone, and gray, brown and white sandstone.*

The geological map, prepared to accompany the memoir of 1844–'47, bears the date of 1844 and is a reprint of the Geological Map of New York, issued in 1842, with additional data on the geology east of the Hudson and Champlain valleys. The long, narrow range of the "Taconic System" is colored drab in its extension from Canada to Westchester County, N. Y. There is no reference to the "Taconic System" in the legend on the map, and the formations composing it are not distinguished by different colors, the reason for which is explained in the description of the map, published on page 361 of the Agriculture of New York, vol i, 1847.†

In 1856,‡ Dr. Emmons divided the "Taconic System" into an upper and a lower division: the upper division taking the formations 4 to 8 of the section of 1844–'47, and the lower division the formations 1 to 3; an arrangement that was repeated in 1859 (Manual of Geology), when the name "Magnesian slate" was replaced by that of "Talcose slate." In the diagram, fig. 10, the formations are represented in the order of succession given in 1856; and, on the map, the geographic area is given within which the typical localities of the various formations occur and also the extension of the latter to the north and south. This is the stratigraphic scheme of the "Taconic System" as arranged by its author from the results of his latest field observations.§

"*Granular Quartz*" (Terrane No. 1, of section on side of map and fig. 10).—Dr. Emmons calls the "Granular Quartz" the basal member of the "Taconic System," and, in his opinion, the base of the Paleozoic sediments on the North American continent. He describes its occurrence in Vermont and follows it, with interruptions, across Massachusetts into the northeastern part of Dutchess County, N. Y., and also south into Putnam and Westchester counties.‖ The stratigraphic

* Loc. cit., p. 61.

† The copy I have of this map was purchased by me from a second-hand book dealer, in 1876. I have reason to state that 3000 copies were originally delivered to the Secretary of State, of the State of New York, by the printers, and I think that copies can still be obtained from the said Secretary's office. despite the published statement that the edition was stolen or destroyed. (See letter of Dr. Emmons to Prof. Jules Marcou: Am. Acad. Arts and Sci., vol. xii, p. 188, 1885, also copied by Dr. Hunt, Am. Nat., vol. xxi, p. 122, foot note 3, 1887).

‡ The first part of this volume is dated 1855. The second part, containing the description of the "Taconic System," was issued in 1856.

§ I shall not comment on the so-called Taconic rocks, as identified by Dr. Emmons in Canada, Maine, Rhode Island, Michigan, and the southern Appalachian region. All those determinations rested on lithologic characters; and the strata referred by him to the "Taconic System" range from pre-Cambrian to the Niagara of the Silurian.

‖ Agric. N. Y., vol. i, p. 86, 1847.

position was determined by its relation to the crystalline rocks beneath and the superjacent strata, as no fossils were known by him from the formation. A talcose conglomerate that is treated as a subordinate member of the "Granular Quartz series" is described as occurring between the quartzite and Primary, in several localities.

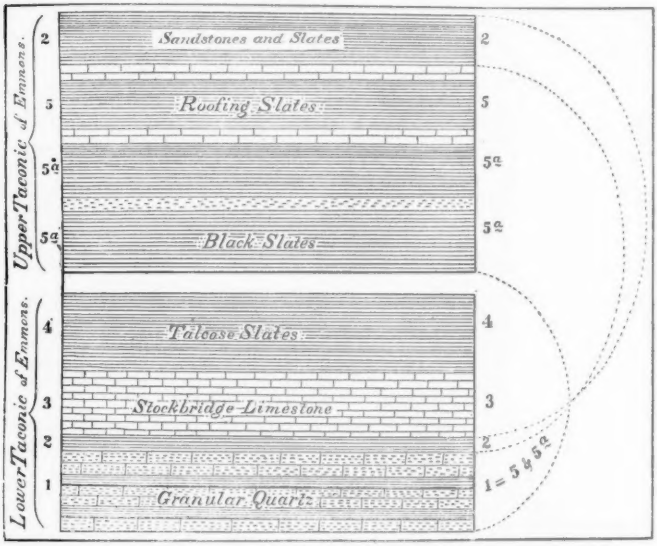


Fig. 10.—A tabular view of the strata as arranged by Dr. Emmons. The figures placed at the sides are equivalent to those used on the section on the side of the map. The dotted lines on the right side show the relation of the "Upper Taconic" to its geologic equivalent the "Granular Quartz."

Conformably resting on the "Granular Quartz," on the north side of Graylock Peak, at the Hopper, he found a bed of "talcose slate," 400 to 500 feet thick, which is represented in the table (fig. 10) by number 2. It appears to be the extension of a formation of more than 2,000 feet in thickness that occurs on the western side of the Taconic range. (See section on the map.)

Stockbridge limestone (Terr. No. 3 of Section and fig. 10).—Upon the slates of Terrane No. 2 a series of limestones and marbles are conformably superimposed that are called by Dr. Emmons the "Stockbridge limestone." This includes all the limestones, "good and bad, in connection with the bed known as marble." A good description of this terrane is given in the memoir of 1844–'47, and again in 1856. It is assigned a thickness of 500 feet, in Saddle Mountain, Mass.

Talcose Slates (Terr. No. 4 of Section and fig. 10). — These slates, which are called "Magnesian slates" in the reports of 1842–'44–'47, were given the name "Talcose slates" in 1856. A thickness of 2000 feet is assigned to them on the Taconic range and they are represented as conformably superimposed upon the Stockbridge limestone.

"*Upper Taconic.*"—In the scheme published in 1844–'47 the Magnesian slate is succeeded by the Sparry limestone, Roofing slate, a coarse brecciated bed, Taconic slate, and Black slate, and on p. 13, Am. Geol., pt. 2, 1856, this succession is recognized. On page 49 (loc. cit.), however, the entire scheme is changed; the Black slate is placed at the bottom of the series and then, in succession, siliceous slates: slates and sandstones, with thin-bedded blue limestones succeeded by thicker beds of sandstone; blue, green, purple and red roofing slates, coarse sandstone and shale passing into conglomerates and brecciated conglomerates. "The latter terminate the series eastward, and geographically near the Hoosick roofing slates. In the foregoing brief enumeration in the ascending order, the rocks follow each other in a conformable position, and beginning with the thin black slates, end in thick bedded sandstones and conglomerates," (loc. cit., p. 50).

In this re-definition of the "Upper Taconic," the Sparry limestone is no longer considered as belonging to it, and I have failed to find it mentioned subsequently as a distinct formation of the "Upper Taconic." The sparry limestone spoken of in describing the "Upper Taconic" section crossing Washington County, refers to the thin interbedded sparry limestones, in which I have found Olenellus and other Middle Cambrian fossils. The sparry limestones west of Hoosick Falls are referred to the Lower Silurian and removed entirely from the "Taconic System."

As is shown by Professor Dana, Dr. Emmons, in 1842, called the Sparry limestone the oldest of the Taconic limestones, and, in 1844, he placed it beneath the Taconic slate and above the Stockbridge limestone.* In 1856,† however, a section was published showing the Taconic Range by C and, at its western base, the limestone (2) is identified with the Stockbridge limestone (2), of B (Graylock Peak). What Dr. Emmons intended by this, and why he did not mention the change in the text, is not explained by him. Professor Dana called my attention to it by letter, and says that he accepts the evident meaning given by the section, which is, that Dr. Emmons identified the Sparry and Stockbridge limestones as one formation. With our present knowledge, this explanation is the only one open to us.

* This Journal, III, vol. xxxiii, pp. 415, 416, 1887.

† Am. Geol., vol. i, pt. 11, p. 19, fig. 2.

In 1859 the section is republished,* but the numbers are omitted from all the formations except those of Graylock Peak. Whether the omission was by design or accident is unknown.

In the black slates, at the summit of the "Taconic System" of 1844–'47 and at the base of the "Upper Taconic" of 1856, Dr. Asa Fitch found a few fossils which he gave to Dr. Emmons, who described two species in the memoir of 1844–'47, under the names of *Elliptocephala asaphoides* and *Atops trilineatus*. In 1859 Dr. Emmons compared these fossils with the Primordial fauna of Barrande, and established their position in the stratigraphic series on paleontologic evidence.† Their reference to a pre-Potsdam horizon, in 1844–'47 and 1856, was on the supposed stratigraphic position of the beds in which they occurred.

Résumé.—It is not necessary to repeat the full and accurate lithologic descriptions of the five terranes (fig. 10) mentioned by Dr. Emmons in 1844–'47 and 1856. They are grouped in fig. 10 to represent his view of their succession within the "Taconic System."

2. *Stratigraphic position of the "Taconic System."*—Dr. Emmons founded the "Taconic System" under the belief that it was composed of older formations than those of the New York Lower Silurian, the base of which was then the well-known Potsdam sandstone. In the memoir of 1842, he says: "But I have, at the head of this section, asserted that the slates and masses of the Taconic System are not related to, or connected with those of the Champlain group. By this I mean that they are not the same rocks in another condition."‡ Again he says: "They are to be considered, however, as furnishing us with a knowledge of that state which immediately preceded the existence of organic beings."§ After further field study his views became more positive in regard to the relation of the Taconic to the Lower Silurian rocks. He says: "I shall take the broad and distinct ground that the Taconic System occupies a position inferior to the Champlain division of the New York system, or the Lower division of the Silurian system of Mr. Murchison."‖

"1. *Position.*—It rests unconformably upon primary schists, and passes beneath the New York system, the oldest and inferior members of the latter being superimposed unconformably upon the Taconic slate."¶ These views were sustained in his publications of 1856, 1859 and 1860.

On the section, accompanying the memoir of 1844–'47, pl. 18, Section I, the strata of the "Taconic System" all dip con-

* Manual of Geology, p. 85, fig. 60.
† Manual of Geology, p. 87, 1859.
‡ Geol. N. Y., pt. 2, p. 138, 1842.
§ Loc. cit., p. 164.
‖ Agric N. Y., vol. i, p. 55, 1847.
¶ Loc. cit., p. 108.

formably to the eastward. On the east they rest unconformably on the primary and, on the west, the Calciferous and Hudson terranes are represented as unconformably superjacent to the Taconic slates. Dr. Emmons says: "This section may be regarded as one of the best for exhibiting and proving the entire independence of the Taconic System from the Primary below and the New York system above." *

Two sections published in 1859 † may be taken as expressing his latest views of the relations of the different parts of the "Taconic System," in its typical area, with the exception of the "Upper Taconic" and the Lower Silurian (Ordovician), on the western side. In these sections, the "Lower Taconic" forms a synclinal with the "Granular Quartz" at the base and then the Stockbridge limestone and Talcose slates, respectively superjacent, the "Upper Taconic" being entirely disconnected from the latter. He held the view, from the first, that the eastward dip of the greater part of the strata of the "Taconic System" resulted from successive uplifts, "which, in consequence of the confined position of the rocks, have often produced local foldings and plications of the strata." ‡ His view of the extent and character of the uplifts was subsequently changed, as is shown by his representation of the position of the sparry limestone in 1842,§ 1844§ and 1855.

In the memoir of 1856 several sections were illustrated and described to show the unconformity between the Taconic slate and the Calciferous sandrock, and thus establish the inferior position of the "Taconic System" to the Lower Silurian (Ordovician) strata. These sections will be spoken of again, under the head of "Discussion and Comparison."

Dr. Emmons correlated the "Taconic System" with the Cambrian system of Sedgwick, in his first memoir of 1842, in the following words: ‖ "The Taconic rocks appear to be equivalent to the Lower Cambrian of Prof. Sedgwick, and are alone entitled to the consideration of belonging to this system, the upper portion [of the Cambrian—C. D. W.] being the lower part of the Silurian System." ¶

Again, in the memoir of 1844–'47, he says, when speaking of the proposed abandonment of the Cambrian System by English geologists: ". . . . were it not for a single fact, the

* Loc. cit., p. 366.

† Manual of Geology, p. 85, figs. 58 and 60.

‡ Geol. N. Y., pt. 2, p. 142, 1842.

§ See Professor Dana, this Journal, 3d Ser., vol. xxxiii, p. 415.

‖ Geol. N. Y., pt. 1, p. 163, 1842.

¶ Dr. T. S. Hunt (Am. Nat., vol. xxi, p. 124, 1887) interprets this passage to prove that Dr. Emmons in 1842 correlated the upper portion of the Taconic with the Lower Silurian of Murchison, but, as I read it, Dr. Emmons refers the Upper Cambrian, not his Taconic, to the Lower Silurian.

writer would freely acquiesce in the decision, so far as the British rocks are concerned. This fact is found in the existence of peculiar fossils on both sides of the Atlantic, which, so far as discoveries have been made, are confined to the slates of the Cambrian and Taconic systems; and now the great object of the writer is to show that the above question has not been settled right, or according to the facts; or, in other words that the Taconic rocks are not the Hudson River slates and shales in an altered state, or that all the Cambrian rocks are not Lower Silurian." *

In the following pages observations and deductions therefrom are given to support the above statement in relation to the "Taconic System," but nothing further is said of the fossils from the Cambrian system, and I am at a loss to know to what species the author referred. Reference is made to the Cambrian sections of Sedgwick, in 1856, to show that although the Cambrian slates are conformably beneath the Coniston limestone bearing Lower Silurian fossils, and hence may be referred to the Silurian, the Taconic rocks are unconformably beneath the equivalent Calciferous sandrock of the New York series and cannot be included with the Lower Silurian.†

Among the letters of Dr. Emmons, published by Prof. Jules Marcou,‡ is one, dated November 19, 1860, in which he says:§

". . . . I do not think him [referring to Barrande] right in maintaining that his Primordial group is a part or parcel of the Silurian: . . . . the Lower Silurian is strictly unconformable to every part of my Taconic series, and this series is . . . . separate and distinct from Silurian."

On the same page, in a letter dated November 20th, 1860, he says: "On reading his [Barrande's] papers, I found that, after all, his Primordial group is *only Lower Silurian*. I conceive we have exactly his *Primordial group* in the band of slates containing the *Paradoxides*. But this band is only a very narrow belt of beds."

In a letter dated December 28th, or 29th,‖ he says, when speaking of the announcement of the *Huronian* System by Logan: "I claimed that the *Huronian* was the *Taconic* System . . . Are you aware that most, if not all, of those beautiful graptolites Mr. Hall refers to the Hudson River group belong to the Taconic System?"

Again, in a letter dated January 23d, 1861:¶ "The acknowledgment of the *Primordial of Barrande in this country* is really one of the finest and best facts in geology, making a *coördination of American and European rocks so complete and harmonious.*"

* Agric. N. Y., vol. i, p. 49, 1847.
† Am. Geol., vol. i, pt. 2, p. 90, 1856.
‡ Proc. Am. Acad. Arts and Sci., vol. xii, 1885.
§ Loc. cit., p. 186.
‖ Loc. cit., p. 188.
¶ Loc. cit., p. 190.

In commenting upon Professor Marcou's reference of the Potsdam sandstone to the "Taconic System," he objects to such references on stratigraphic grounds, as is shown by his letter of January 28th, 1861.

These later letters of Dr. Emmons prove that he considered the "Taconic System" to include the Huronian of Logan and the graptolite-bearing shales of the Hudson valley, from his letter of November 20th, 1860, he also included the Paradoxides beds of the "Upper Taconic" which equal the Primordial group of Barrande, which "is *only* Lower Silurian," and declared that "the Lower Silurian is strictly unconformable to every part of my Taconic series."

Despite the statements made in the preceding paragraph, I think we may say that Dr. Emmons regarded the original "Taconic System" as stratigraphically unconformable and subjacent to the Potsdam sandstone of the Lower Silurian of the New York section and believed it to rest unconformably upon the crystalline gneiss at its base and to form a great system of sedimentary rocks between the gneiss and Potsdam sandstone.

Comparison and Discussion.

Comparison.—A comparison of the geology of the Taconic area as known at the present time with the geology of the same area as known to Dr. Emmons develops several points of agreement. His lithologic descriptions are usually easily verified; and the general dip and arrangement of the strata within the "Taconic System" are the same with the exception of the relations of the strata referred to the "Lower" and "Upper Taconic."

The points of disagreement are: the identification of the geologic age of the formations of the "Lower Taconic;" the stratigraphic relations of the "Lower" and "Upper Taconic;" the stratigraphic relations of the "Upper Taconic" and the superjacent Silurian formations, and the value of the stratigraphic and paleontologic identifications of the age of the "Upper Taconic" slates.

1. Dr. Emmons considered the "Lower Taconic" to be composed of three non-fossiliferous pre-Silurian formations—"Granular quartz, Stockbridge limestone and Talcose slates" (see fig. 10) that were unconformably superjacent to the crystalline gneisses beneath and conformably subjacent to a great series of slates, forming the "Upper Taconic," that, in turn, were unconformably subjacent to the lowest of the Lower Silurian formations, the Potsdam sandstone.

We now know that the base of the "Taconic System," the "Granular Quartz," contains fossils that prove it to be the geologic equivalent of the greater portion of the "Upper Ta-

conic;" also, that it is the arenaceous deposit that accumulated along the pre-Paleozoic shore while the siliceous, argillaceous and calcareous muds, now forming the "Upper Taconic," were being deposited to a greater depth off the immediate shore line. This entirely negatives the conclusion of Dr. Emmons, that the "Upper Taconic" slates were superjacent to the "Lower Taconic" rocks.

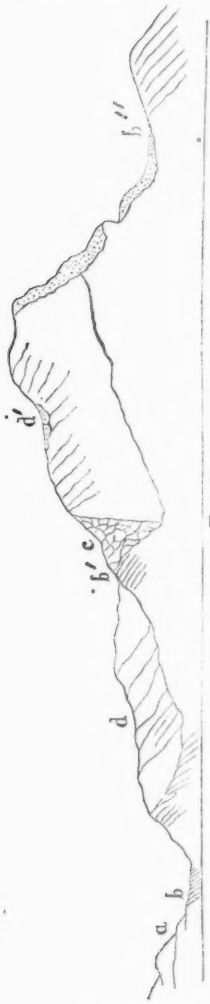


Fig. 11.

2. The second formation, the "Stockbridge limestone," has afforded fossils that prove it to be the equivalent of the Trenton, Chazy and Calciferous limestones of the Lower Silurian of the New York section, and it is not, as claimed by Dr. Emmons, a peculiar pre-Silurian deposit of limestone.

3. Conformably resting upon the "Stockbridge limestone" the "Talcose slates" (Terr. No. 4) occupy the stratigraphic position of the Hudson Terrane, in the New York section, and a species of graptolite, abundant in the Hudson Terrane, occurs in the "Talcose slates" near Hoosick, N. Y.

We have next to consider the relations of the "Upper Taconic" slates to the superjacent Silurian formations and the value of the stratigraphic and paleontologic identifications of the age of the "Upper Taconic."

In the first published section* of the "Taconic System," the "Shales of the Champlain Group" are represented as resting unconformably against, and on, the Taconic slates. This is repeated in the section published in 1844–47.† These two sections are largely theoretic, but, on page 89 (loc. cit.), Dr. Emmons gives a section of Bald Mountain, in the town of Greenwich, Washington County, N. Y., which is here reproduced (fig. 11).

This section is intended to show the unconformity between the Taconic slates, *b*, *b'*, *b''*, and the Calciferous formations, *d*, *c* and *d'*, it being assumed by Dr. Emmons that the slates, *b*, *b'* and *b''*,

* Geol. N. Y.; Rep. Second Geol. Dist., p. 145, fig. 46, 1842.
† Agric. N. Y., vol. i, p. 63, fig. 7, 1847.

were identical, and that *d'* was a mass of the Calciferous sandrock of the New York section, and, also, the mass represented by *c*. I began the investigation of this section, in 1887, by searching for fossils in the various formations, and then studied its stratigraphy. The result is given in the section represented by fig. 12. I found that the blue limestone, *c*, of figs. 11 and 12, extends beneath the shales and limestones capping the mountain and that it is interbedded in the shales and considerably broken and displaced on the south edge of the mountain, toward the fault line, as shown in fig. 12. *Leperditia fabulites* was found in it, on both the west and south side of the mountain. The true *Calciferous sandrock*, of the New York section, is shown at E, interbedded in the shales, S and X. In the limestones, *d*, forming the summit of the mountain, in fig. 11, I found *Lingulella celata*, *Linnarssonia Taconica*, *Obolella* sp. undet., *Hyolithellus micans*, *Microdiscus speciosus* and *Olenellus Thompsoni:* all of which are Middle Cambrian species and characteristic of the slates, *b''*, in fig. 11, east of the mountain. Dr. Emmons identified this mass of strata, *d'*, with the Calciferous sandrock on lithologic characters, overlooking the fact that a similar rock might occur in his Taconic series. Two miles to the north, on the farm of D. Walker Reid, this belt of calciferous rock is over 600 feet thick, it contains a characteristic Middle Cambrian fossil, *Hyolithellus micans*, and is conformably subjacent and superjacent to shales and limestones, containing over fifteen characteristic species of Middle Cambrian fossils.

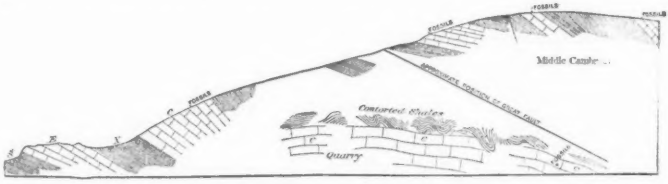


FIGURE 12.—Section of Bald Mountain from the south. The profile of the mountain and position of the Cambrian and Lower Silurian rocks are taken from a photograph. The "Upper Taconic"=Cambrian slate, sandrock and limestone are shown to the right of the fault, and *c*=Chazy limestone; *x*=dark shales, interbedded between *c* and the Calciferous sandrock, E; *s*=dark argillaceous shales beneath the Calciferous sandrock.

The section of Bald Mountain proves that the strata of the "Upper Taconic" are there pushed over on to the Chazy Terrane, and that the "Upper Taconic" is not unconformably subjacent to the latter or to the Calciferous sandrock.

To the north of Bald Mountain, about two miles, a somewhat similar mass of limestone to that of *c* is adjacent to the fault

line and contains: *Orthis testudinaria*, *Strophodonta alternata*, Maclurea and other gasteropods, *Calymene senaria* and fragments of *Asaphus platycephalus*. Details of all the exposures observed where the "Upper Taconic" shales and the rocks of the Lower Silurian come in contact will be given in a report on the geology of Washington and Rensselaer counties.

Another section,* taken by Dr. Emmons just east of the village of Whitehall, is reproduced in fig. 13. The object of this is to show the presence of a mass of calcareous sandrock, *d'*, resting unconformably upon the Taconic slate, which Dr. Emmons identified as the Calciferous formation of the Lower Silurian. I studied the section in 1886, also in 1887, and found Cambrian fossils, represented by the heads of the Olenellus and fragments of Ptychoparia, imbedded in the sandrock, *d'*, and also found the strike and dip of the sandrock and shales to

FIGURE 13. *a, a.*—Easterly prolongation of the mountain, which is surmounted by the Calciferous sandrock: *b b*, Tertiary clay; *c, c*, Taconic and black slate; *d, d*. Calciferous sandstone, unconformable to the Taconic slates, and dipping southeast at an angle of 40–45°. (After Emmons.)

be conformable. Another section on the same page† is entirely within the Champlain series on my map and west of the great fault line. It is 30 miles north of Bald Mountain and in the township of Whitehall. I found the Potsdam sandstone at its base, in the village of Whitehall, and then, superjacent to it, the Calciferous Terrane, with a band of dark argillaceous shale, lithologically similar to that of the Hudson Terrane, between it and the superjacent Chazy limestone. Resting on the Chazy limestone there is a second band of dark shales, 175 feet thick, that is subjacent to the Trenton limestone, and the latter is subjacent to the argillaceous and sandy shales of the Hudson Terrane. The strata of the entire section are conformable; and the limestones were identified by contained fossils. East of the shales of the Hudson Terrane, the existence of the great fault line is shown by the presence of strata, resting against, and on, the Hudson Terrane, that carry Middle Cambrian fossils. These interbedded shales, between the limestones, and, also, the Hudson shales, were considered, by Dr. Emmons, to be of Taconic age, and the limestone to lie unconformably above them.‡

* Agric. N. Y., vol i, p. 56, fig. 2, 1847. † Loc. cit., p. 56, fig. 3.

‡ One fact, not recognized by Dr. Emmons at Bald Mountain or along the great fault line, is that in many localities belts of dark argillaceous shale occur between the Calciferous, Chazy and Trenton limestones; that, in others, one or more of these formations is entirely a shale formation, and that the Potsdam Ter-

Another illustration of the supposed overlap of the Champlain upon the Taconic Terrane is given in the American Geology, pt. 2, p. 72, fig. 12. It is in the township of Greenbush, opposite Albany, N. Y, on Cantonment Hill. There a mass of the Trenton limestone is caught on the line of the great fault separating the Champlain and Cambrian strata, as at Bald Mountain and other places in Washington county, and, also, in Vermont. The strata of the Hudson and Trenton Terranes are broken and displaced, but there is no evidence that the Trenton was deposited upon the upturned edges of the Cambrian or "Upper Taconic" slate; and, on the line of the same fault, 20 miles to the south, in the township of Schodack, Mr. S. W. Ford discovered an unconformable contact between the dark drab siliceous and micaceous shales of the Cambrian and the dark argillaceous shales of the Hudson Terrane.* Mr. Ford kindly took me to the locality which he has so well described, and I saw the "hade" of the fault, the slickensides on the opposing surfaces, and broke out graptolites from the Hudson shales beneath, and within six inches of, the fault line. A short distance south the limestones interbedded in the dark-drab shales gave us an abundance of characteristic Middle Cambrian fossils. For the details of this overthrust of the Cambrian upon the Hudson Terrane, see Mr. Ford's paper.

Dr. Emmons illustrates another section† that shows the same errors of observation as in the figure of the section at Cantonment Hill. Again, in fig. 22,‡ of the section at Snake Mountain, in Vermont, the error made at Bald Mountain is repeated, for it is now well known that the supposed overlying Calciferous (?) sandrock ("Red sandrock") is a stratum of the Cambrian pushed over on to the Lower Silurian Terrane,§ and not a Lower Silurian formation, unconformably superjacent to the "Upper Taconic" strata.

All the overlying limestones that he mentions as unconformably overlying the Taconic rocks, with the exceptions noted, where they contain Middle Cambrian fossils, are west of the

rane, off shore, was originally deposited either as a calcareous or argillaceous mud. It was owing to this oversight that he frequently identified the shales of the Champlain series as those of the Taconic. Another phenomena not understood by him, was the creeping or protruding of shales from beneath heavy masses of limestone, on account of the pressure squeezing the shales out and turning them up. In this way many of his non-conformities of dip appear to have been erroneously observed. In many instances he did not recognize the lithologic differences between the great mass of his Taconic slate and that of the Hudson Terrane. The black shale (marked "Taconic," in the Bald Mountain section, *b*, *b'*, fig. 11) is not similar to the shale containing the trilobites, east of the great fault, yet he identified them as lithologically the same formation.

* This Journal, vol. xxix, p. 16, 1885.

† Am. Geol., vol. i, pt. 2, p. 79, fig. 14, 1856.

‡ Loc. cit., p. 87.

§ This Journal, III, vol. xiii, p. 413, 1877.

fault line separating the Cambrian and Silurian Terranes; and the shales west of the fault belong to the Silurian, not to the "Upper Taconic" Terrane. The line of outcrop of the Cambrian Terrane is well marked, and I have endeavored to locate it accurately on the map. The great Appalachian fault separates the Potsdam and other Silurian rocks from the Cambrian; and nowhere on the western side of the Cambrian Terrane, to my knowledge, either in New York or Vermont, is there a deposition contact, either conformable or unconformable, between the rocks of the "Taconic System" and the Potsdam or other Silurian terranes. I have examined all the localities cited by Dr. Emmons and, later, by Professor Marcou and, in every case, the great fault separates the strata of the two systems. In fact, the Taconic usually rests on the Silurian strata as the result of the overthrust from the east; and, as will be shown in my report on Washington County, N. Y., the strongest proof of the presence of a fault line is shown by the mechanical disturbance of the Cambrian strata, on the eastern side of the fault.

That the Taconic slates are unconformably pre-Potsdam, is yet to be proven in any area known to Dr. Emmons, either in New York or Vermont. Where they pass beneath the shale representing the Potsdam horizon, beneath the Stockbridge limestone in the Taconic Range, they are conformably pre-Potsdam, but this fact was unknown to Dr. Emmons.*

Résumé.—As the result of these comparisons, we find that the "Lower Taconic" is essentially a repetition of the lower Silurian (Ordovician) section of the Champlain valley. It differs in lithologic details and in having a less abundant fauna in the typical Taconic area

The "Upper Taconic" is found to be conformably subjacent to the "Stockbridge" limestone of the "Lower Taconic," and to include the Potsdam horizon at or near its upper portion. Its base is not unconformably subjacent to the Lower Silurian Terrane, as maintained by Dr. Emmons and Professor Marcou.

The value of the paleontologic identification by Dr. Emmons of the "Upper Taconic" slate as a pre-Potsdam formation will now be considered.

* Professor Henry D. Rogers, in his address before the meeting of the Association of American Geologists and Naturalists, held at Washington, in May, 1844, said, when speaking of the unconformity claimed by Dr. Emmons between the Champlain and Taconic rocks: "I must take the liberty of expressing my disbelief of any such unconformity, and of observing that in the prolongation southwestward of this altered and plicated belt as far as the termination of the Blue Ridge in Georgia, a distance of 1000 miles, no interruption of the general conformity of strata has ever met the observation of my brother or myself."—(Amer. Jour. Sci., I, vol. xlvii, p. 152, 1844).

On page 63, of the Agriculture of New York (vol. i), under the heading "Black Slate," Dr. Emmons says: "I shall describe the rocks in the descending order: and by so doing, I commence with the mass of which there is some doubt whether it ought to be considered as a distinct rock or merely the upper portion of the Taconic slate; still I am disposed to regard it now as a separate and distinct rock, forming, so far as examinations have been made, the highest member of the Taconic system. Circumstances which have led to the separation of this from the rock referred to are of an interesting character; interesting particularly as being connected with the discovery of crustaceans where they were least expected."

Dr. Asa Fitch found the fossils from the "Black Slate," in 1843, and gave them to Dr. Emmons, who described two species of trilobites under the names of *Atops trilineatus* and *Elliptocephala asaphoides;* the first he thought to be an intermediate genus between the Calymene and Triarthrus; of the second, *Elliptocephala asaphoides*, he compared parts with similar parts of the *Asaphus tyrannus*, of the Lower Silurian of England.*

On page 68 of the same memoir, under the head of "Fossils peculiar to the Taconic Slate," he describes two species of Annelid trails: one from the Green Taconic slate, and the other from the sandstone in Washington County. He follows this with a description of nine species of what appeared to be trails from the slates of Waterville, Maine. It appears from this that Dr. Emmons considered these various trails to be "fossils peculiar to the Taconic slate," and that the trilobites which he described he did not consider, at that time, as typical of the "Taconic System," for he says (loc. cit., p. 64), in speaking of the "Black Slate:" "Assuming that its fossils are distinct from the fossils of this and other systems," etc.

In his conclusions, he says:† "The Nereites and other fossils of the Taconic slate are unknown in any of the members of the Champlain group. In addition to which, it is important to bear in mind the fact that in this group the Mollusca of the New York system are also wanting."

In 1856,‡ he referred the Black slates to a position above the Talcose slates of the "Lower Taconic," thus making them the base of the "Upper Taconic" series. On page 98, loc. cit., the argument is made that the "Taconic System" is peculiar in its contained organisms, and that he has the right to consider the absence of certain Silurian fossils as evidence that the Taconic was not of Silurian age. As has been shown in the first part of this paper, the limestones of the "Lower Ta-

* Loc. cit., pp. 64, 65.
† Loc. cit., p. 108.
‡ Am. Geol., pt. 2, p. 49, 1856.

conic" carry characteristic Lower Silurian (Ordovician) fossils, as, also, do the shales overlying the limestones.

In 1859 (Manual of Geology, p. 87), Dr. Emmons for the first time compared his *Elliptocephala asaphoides* with the genus Paradoxides, of Barrande's Primordial Zone, stating that the Taconic Paradoxides is also Silurian, and hence it is shown that the Primordial Zone, in Bohemia, is in coördination with the upper series of Taconic rocks. This statement is the first known to me upon which, either by paleontologic or stratigraphic evidence, Dr. Emmons could base his assertion that any portion of the "Taconic System" was of pre-Potsdam age.

The want of clearness in his views is well shown by the extract already quoted from his letter of Nov. 20, 1860, published by Prof. Marcou. "His [Barrande's] Primordial group is *only Lower Silurian.* I conceive we have exactly his *Primordial group* in the band of slates containing the Paradoxides."—What becomes of the stratigraphic break between the Lower Silurian and Taconic rocks if the "Black slates" are still retained in the "Taconic System," remains unexplained. If removed the fossils go into the Lower Silurian with it.

Dr. Emmons described several species of graptolites* from the "Taconic System," the majority of which are now known to also occur in the Hudson Terrane, in the valley of the Hudson. On the map, I have given the distribution of the Hudson Terrane in the Taconic area, as determined by stratigraphic and paleontologic evidence. It is in the central belt, carrying the red slates, that the graptolites occur which led Dr. Emmons to include, as a matter of necessity, if he put the red slates in the Taconic, the dark, argillaceous shales of Hudson Terrane at Troy, Albany, and Baker's Falls, in the Hudson Valley, for they contain the "beautiful graptolites"† referred to by him in 1860. At Albany, N. Y., however, the graptolite beds contain a characteristic Trenton-Hudson fauna.‡ This removes a considerable portion of the "Upper Taconic" strata from the "Taconic System."

* Am. Geol., vol. i, pt. 2, pp. 104–111, 1856.

† See letter to Prof. Jules Marcou; Proc. Am. Acad. Arts and Sci., vol. xii, p. 188, 1885.

‡ Mr. C. E. Beecher found three of the same species of graptolites (*Climacograptus bicornis*, *Dicranograptus ramosus* and *Diplograptus mucronatus*) as those found by me in the "Taconic Slates" of Washington and Rensselaer counties, associated with Brachiopoda, 5 species; Lamellibranchiata, 16 species; Pteropoda, 2 species; Gasteropoda, 3 species; Cephalopoda, 2 species; Annelid, 1 species; Crustacea, 1 species, and Trilobita, 2 species. For names of species, see Mr. Beecher's paper. (Thirty-sixth Ann. Rep. N. Y. State, Mus. Nat. Hist., p. 78, 1884).

Résumé of the Paleontologic Evidence.

(1.) The trilobites described in 1844–47, from the "Black Slate," were referred to the highest member of the "Taconic System," on stratigraphic evidence.

(2.) The same trilobites were referred to the lowest member of the "Upper Taconic," on stratigraphic evidence, in 1856.

(3.) In 1859 they were for the first time referred to a pre-Potsdam position by comparison with a fauna whose position had been stratigraphically determined in relation to the Silurian fauna.

(4.) The Nereites and other trails with the exception of the two from Washington County, N. Y., described as typical of the "Taconic System," have not yet been stratigraphically located in the geologic series.

(5.) The graptolites referred to the "Taconic System" form a portion of the fauna of the Hudson Terrane.

Discussion.—There is not much opportunity for a discussion of the geologic age and position of the "Lower Taconic" rocks. The thorough work of Professor Dana practically settled those points before I began my investigation. Dr. T. S. Hunt opposed Professor Dana's conclusions, basing his dissent on the result of his own studies of the geology of southeastern Pennsylvania and, on his acceptance of certain theoretic views in regard to the lithology of the "Lower Taconic" rocks. He argued that the "Lower Taconic" was the typical Taconic System and of Archean age,* and that Professor Dana's interpretation of the stratigraphy was not sufficient, without the aid of fossils, in the typical Taconic region, to establish the Lower Silurian age of the Stockbridge limestone or the crystalline marbles of the Lower Taconic. With the facts presented in this paper, however, I do not think that Dr. Hunt can claim support for his views without first substantiating them by researches in the Taconic area, a matter that he has apparently not given his attention,† heretofore.

*("Taconic Question in Geology;" Min. Physiology and Physiography, p. 582, paragraph 92, 1886). "92. Considering the pre-Cambrian age of the Lower Taconic to be established, as well as its distinctness alike from the older crystalline rocks below and from the Cambrian series above, to which Emmons had given the name of Upper Taconic—it was proposed by the writer, in 1878, to restrict the term Taconic—for which the alternative name of Taconian was then suggested.—to the Lower Taconic of Emmons." For other views held by Dr. Hunt, see Am. Jour. Sci., 3d ser., vol. xxxiii, pp. 417, 418, 1887.

†Some of Dr. Hunt's errors consist: 1. In relying upon a lithologic theory based upon observations made far distant from the Taconic area. 2. His acceptance of Dr. Emmons's theory of the stratigraphic position of the "Lower Taconic" strata without personal investigation when it was well known that *all* of Dr. Emmons's contemporary geologists opposed the "Taconic" theory. 3. His assuming that it was largely personal opposition to Dr. Emmons that led all geologists who investigated the Taconic area to decide against the "Taconic" theory. 4. His ignoring all stratigraphic and paleontologic evidence published by Professor

Professor Dana was in accord with the opinion of Professors W. B. and H. D. Rogers, Edward and C. H. Hitchcock, W. W. Mather and James Hall, as well as with the results of his own field studies, when he called the "Granular Quartz" Potsdam, the "Stockbridge limestones, Lower Silurian (Calciferous-Chazy-Trenton) and the overlying "Talcose" shales the Hudson River formation. He held the opinion that the "Lower Taconic" was the typical "Taconic System," as first defined in 1842, but as that was proven to be Lower Silurian in age the "Taconic System" could not longer be recognized. In opposition to this Professors Marcou and Winchell argue that if the "Lower Taconic" was of Lower Silurian age the "Upper Taconic" contains Primordial fossils and is, therefore, equivalent to the Cambrian; and, as the discovery of fossils in the "Upper Taconic" was made before typical Primordial fossils were published from Sedgwick's Cambrian System, the name Taconic had priority over that of Cambrian and should be used in place of it to designate the strata containing the First or Primordial fauna of Barrande.

I was influenced by the statement made by Dr. Emmons that the slates of the "Upper Taconic" were unconformably beneath Lower Silurian strata, and, also, by the views of Professors Dana and Marcou when, in 1885, I wrote my observations, "On the Use of the Name Taconic," in the introduction to Bulletin 30, of the U. S. Geological Survey. I was satisfied from the evidence presented by Professor Dana, that the limestones of the "Lower Taconic" belonged to the Calciferous-Chazy-Trenton Terrane, and that the overlying schists were properly referred to the Hudson Terrane. The reference of the quartzite beneath the limestone to the Potsdam horizon, also appeared to be consistent with the data known to him. I was but partially convinced, however, from the evidence presented by Dr. Emmons and Professor Marcou that the "Upper Taconic" slates were stratigraphically pre-Potsdam, or that there was a valid claim for the substitution of the name Taconic for that of Cambrian.

Professor Jules Marcou, although a persistent advocate for the use of the name Taconic, did not go to the typical Taconic area to study the "Taconic System," but studied the extension of the "Upper Taconic" slate and shales in northern Vermont, and identified the "Upper Taconic" as the true "Taconic System." I have carefully examined the localities where he describes the occurrence of a non-conformity between the Georgia slates and the superjacent so-called Potsdam sandstone and at none of them

Dana and others within the past fifteen years on the ground that the writers were putting forth the "old metamorphic hypothesis" of Mather, Rogers, etc. (See Am. Nat., vol. xxi, pp. 114–320, 1887).

could I find a trace of the Potsdam sandstone. The sandstone referred to the Potsdam is of Middle Cambrian age and, at Parker's farm contains two of the same species of fossils that occur in the slates conformably subjacent to the sandstone. The only non-conformity found is formed by the overthrust of the Georgia or Cambrian strata upon the Lower Silurian Terrane, just as at Bald Mountain in Washington County, N. Y., Snake Mountain in Vermont and all along the line of the great fault, wherever outcrops of the two systems occur.

His extension* of the "Taconic System" to include the Potsdam sandstone is in opposition to all of Dr. Emmons's views of the relations of the Taconic and Potsdam strata, as Dr. Emmons founded the "Taconic System" largely on the belief that a great stratigraphic break existed between the Potsdam and Taconic, and that the fauna of the Taconic was unlike that of the "Champlain group," of which the Potsdam formed the base.

Dr. Emmons's errors are nearly all traceable to his trust in the lithologic characters of the various formations within the Taconic area. He established the "Taconic System" in 1842, on the differences in the lithologic characters of the Taconic rocks and those of the New York 'Lower Silurian.' The unconformity between the "Taconic System" and "Champlain" series, announced in 1844–'47, was primarily based on the similarity of the lithologic characters of the Calciferous sandrock of the Lower Silurian and the calciferous sandrock of what we now know to be, from its contained fossils, a part of his "Upper Taconic" series. Again, when the latter (calciferous sandrock of the Cambrian) was pushed over on to the dark shales of the 'Lower Silurian,' on the line of the great fault, he identified the latter shales with the "Upper Taconic" shales, and thus obtained an unconformity, as at Bald Mountain, between the Lower Silurian and Taconic strata. He failed to recognize the fact, shown along an outcrop of a hundred miles or more, that the Potsdam and, frequently, the Calciferous Terranes were represented in the geologic sections by a shale undistinguishable from the shale of the Hudson Terrane; also, that the same conditions occur in the Champlain valley, in the towns of Fort Ann, Kingsbury, and Hartford, Washington County, N. Y., and that, in several localities, the Trenton limestone is replaced by shale. This explains much of the confusion in his stratigraphy and, also, in that of Professor Jules Marcou, in northern Vermont, who was misled in the same manner. The shales containing the Primordial fauna are usually lithologically dissimilar from the dark argillaceous shales of the Lower Silurian,

* Proc. Bost. Soc. Nat. Hist., vol vii, p. 371, 381. 1860.

but, as Dr. Emmons included the dark graptolitic-bearing shales of the Hudson Terrane, within the Taconic area, in the "Upper Taconic," he necessarily compared and identified the black shales of the Lower Silurian with the "Black Slate" of the "Upper Taconic." He could scarcely do otherwise, when the stratigraphy along the western side of the "Taconic System" supported his theory, if such an identification of the shale was made.

The fact that the Potsdam sandstone, as a lithologic formation, is a local deposit in the immediate vicinity of the Adirondack mountains and that the sediments being deposited at the other localities at the same time, embedding similar organic remains, were argillaceous, siliceous and calcareous muds, does not seem to have impressed him, although he devotes many pages of his various memoirs to the description and discussion of the lithology of the Taconic and Lower Silurian rocks.

Dr. Emmons was not a collector of fossils, or he would have found them in nearly all the formations within the Taconic area; and I think that no student conversant with the faunas of the Lower Silurian and Cambrian terranes will long hesitate in concluding that he did not have sufficient critical knowledge of the faunas to which the fossils belonged that he did obtain, to identify the strata from which they came on paleontologic evidence otherwise he could not have so confused them.* When Dr. Fitch gave him the fossils that he had found in the "Black Slate," two miles north of Bald Mountain, in 1843, he at once referred them to a pre-Potsdam horizon, on *stratigraphic* evidence, without making any comparisons with a fauna which he knew to be pre-Potsdam at some other locality. In fact, no such data were at his command at that time, and the reference of the fossils to a pre-Potsdam horizon was based entirely upon the fact that they were in strata which he considered to be situated unconformably beneath the Potsdam sandstone or, in its absence, the Calciferous sandrock.

I wish to mention here that, in 1847, Dr. Emmons did not consider the two species of trilobites as characteristic of the true Taconic slate, but of the overlying "Black Slate," which he considered to be pre-Potsdam, from the evidence of the Bald Mountain section. I also call attention, again, to the fact that there was no valid stratigraphic evidence of the pre-Potsdam age of the "Black Slate;" moreover, as I have shown, the "Black Slate" is the lowest member of the "Taconic System" and not the highest, as stated by him, in 1847, or next above

* It is not practicable for me, owing to want of space, to give a full analysis of the paleontologic work done by Dr. Emmons in connection with his argument for the Taconic system. This will appear in my report on the geology of Washington County, N. Y.

the "Lower Taconic," as stated in the scheme of 1856. (See fig. 10.)

The comparisons made by Dr. Emmons between the fossils of the "Black Slate" and the Primordial fauna of Barrande, in 1859, came too late to anticipate the identification of the Primordial fauna in the Cambrian of Sedgwick, for the Cambrian System, as used by me, was correctly identified, paleontologically, by M. Barrande, in 1851.*

As I have repeatedly stated, Dr. Emmons assigned the two species of fossils described by him from the "Upper Taconic" slates to a pre-Potsdam horizon, on stratigraphic evidence that, on investigation, proves to have been based on errors of field observation. Such being the case, there was no proof of the position of the fauna, as he had no means for comparison with a similar fauna that had been stratigraphically located elsewhere in the geologic series. It was a *fortunate happening* that the "Upper Taconic" fossils proved to be of pre-Potsdam age, and not a scientific induction based on accurate observations or comparisons.

M. Barrande visited England in 1851 and determined the age of the Primordial fauna found in the typical Cambrian area of Wales before he knew of the existence of the vestige of the Primordial fauna published by Dr. Emmons. Subsequently, upon the evidence of Dr. Emmons's published stratigraphic sections, showing that he, Dr. Emmons, knew the fossils to be stratigraphically pre-Potsdam, M. Barrande was misled into crediting him with a discovery (in 1859) that was based on errors of field observation, and I did the same thing in the introduction to Bulletin 30, U. S. Geological Survey, in 1885.

* January 20th, 1851, M. J. Barrande read a paper before the Geological Society of France, upon the "Silurian Terrain of England." He presented a sketch of a section from Wales showing the Archean and, resting upon it, the stages corresponding to the stages C and D, of the Bohemian section, or the strata of the First or Primordial fauna and the Second or Lower Silurian fauna. Above the Lower Silurian the Upper Silurian is shown as resting unconformably upon the latter. In this paper the Lower Cambrian of Sedgwick is identified by organic remains, through comparison with the established succession of fossils in the Bohemian Basin. (Bull. Soc. Géol. de France, t. viii, pp. 207–212, 1851).

[To be continued.]

Art. XXVII.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGee.

(Continued from page 143.)

The Appomattox Formation.

Character and Distribution.—Near the summits of the bluffs overlooking the Rappahannock river from the southward a mile or two west of Fredericksburg, a distinctive, stratified, orange-colored sandy clay is found reposing upon Potomac sandstone, from which it is readily distinguishable by its greater homogeneity, the more complete intermingling of its arenaceous and argillaceous materials, its more regular stratification, and its more uniform and predominantly orange color. It is as readily distinguishable from the Columbia deposits, on the other hand, by its vertical homogeneity, its comparatively regular stratification, its distinctive color, and its greater range of altitude—extending as it does from tide-level to the highest eminences of the Piedmont escarpment between the Rappahannock and the Roanoke. At Fredericksburg the deposit is commonly thin and confined to limited isolated areas, especially at the higher levels, and it appears at but a single locality (Potomac creek) north of the immediate valley of the Rappahannock; but it rapidly increases in thickness and continuity to the southward. About the confluence of the Ni, Po, and Ta rivers it forms the surface over a meridional zone fully 10 miles wide; it is well exposed in the bluffs of the Taponi, along which it reposes upon the fossiliferous Eocene; and in the bluffs of the Mattaponi and the Anna rivers, as well as over the intervening divides, it is the prevalent surface formation, maintaining the characteristics exhibited at Fredericksburg save that it is frequently gravelly. In the vicinity of Richmond it is occasionally exposed toward the summits of the river bluffs, but is there less conspicuous than the subjacent Miocene, Eocene and Potomac deposits; while still further southward it continues to thicken and expand.

The distinctive orange-colored sands and clays of the formation are typically exposed on and near the Appomattox river from its mouth to some miles west of Petersburg. A mile below Petersburg they are found at tide-level in the river banks; in the eastern part of the city they appear overlying the fossiliferous Miocene beds mid-height of the bluffs; and at the "Crater" a mile and a half east, in the railway cuttings in the southwestern part, and on the upland two miles west of the city, they occupy the highest eminences. The zone of outcrop here is at least 30 or 40 miles wide. As at Fredericksburg, the deposit is a regularly but obscurely stratified orange-

colored clay or sand, sometimes interbedded with gravel or interspersed with pebbles. Perhaps the best exposure is at the "Crater" (a pit formed by the explosion of 8,000 pounds of powder in a mine carried by Federal engineers beneath a Confederate fort, July 13, 1864). Here the principal material is a dense, tenacious clay, orange, gray, pink, reddish, and mottled in color, plastic yet firm when wet, and so hard and tough when dry that medalions stamped from it as souvenirs are as durable as rock—indeed the well known strategetic measure to which the "Crater" is due was rendered successful by the firmness and tenacity of the clay through which the entire mine was excavated save where it barely touched the subjacent fossiliferous glauconitic sands of the Miocene. At Butterfield's bridge in the southwestern part of Petersburg the railway cutting exposes some 20 feet of plastic clay (like that found at the "Crater"), pebbly and sandy clay, and cross-laminated clayey sand, all predominantly orange-colored, in alternating beds; and it is noteworthy that here, as at some other points, flakes and lines of white plastic clay similar to those of the Potomac arkose are occasionally included in the formation.

The formation continues to thicken and expand south of the Appomattox river, until it forms the surface everywhere in the vicinity of the fall-line save where it is cut away by erosion or concealed beneath the Columbia deposits. Typical exposures occur along the Atlantic Coast Line railway at several points, notably on the Roanoke opposite Weldon, N. C., where a few pebbly bands are intercalated within the regularly stratified orange-colored clays and sands.

In brief the inland margin of the Appomattox formation, as exposed north of Roanoke river, is a moderately regularly stratified sand or clay with occasional intercalations of fine gravel, generally of pronounced orange hue, and without fossils; it reaches a thickness of probably 50 to 100 feet and forms the predominant surface formation over a zone 40 or 50 miles wide on the Roanoke, but attenuates and narrows northward, finally disappearing at Potomac creek, 4 or 5 miles north of Fredericksburg; and although it appears to thicken seaward it soon disappears beneath tide level and newer deposits.

Stratigraphic Relations.—At Fredericksburg the formation reposes, sometimes unconformably and again without visible unconformity, upon the lower member of the Potomac, and like relations are frequently exhibited in the vicinity of Richmond and Petersburg; in the bluffs of the Taponi generally, and of the Pamunkey two or three miles north of Hanover Court House, it rests unconformably upon fossiliferous Eocene beds; at the "Crater" and at a number of other localities in the vicinity of Petersburg it rests without visible unconformity

upon fossiliferous Miocene beds; in the western part of Petersburg it lies directly upon the Piedmont crystallines; two miles northeast of Bellfield it cannot be clearly demarked from the fossiliferous Miocene; and at Weldon it rests upon deeply ravined crystalline rocks save where inconspicuous remnants of Potomac arkose intervene. It therefore reposes upon a foundation made up alike of Piedmont crystallines, Potomac deposits, Eocene clays and greensands, and Miocene beds, all of which, with the possible exception of the last, were deeply degraded before its deposition.

The formation is overlain only by the alluvium of small streams, æolian sands, etc., on the broad plains between Petersburg and Weldon, by occasional accumulations of wave-washed debris derived from its own mass in the extensive Quaternary terraces prevailing in its area, and by the characteristic clays, sands, and gravels of the Columbia formation in the vicinity of the larger streams.

Taxonomy.—Since the formation has yielded no fossils, its age and relations can only be determined by stratigraphy, degree of alteration of materials, depth of erosion, etc. It is manifestly newer than the fossiliferous Miocene upon which it rests, and older than the Columbia formation by which it is overlain; and its fresh aspect and comparatively slight erosion indicate that its place is much nearer the later than the earlier of these formations.

The Appomattox formation is stratigraphically continuous with an extensive series of clays and sands investigated in North Carolina by Kerr, and referred by him first to the Quaternary and subsequently to the Eocene. Since the rôle played by these deposits is increasingly important southward, and since they have been casually recognized at many points in the Southern Atlantic slope, it is probable that they will be found to reach considerable volume in South Carolina, Georgia, and Alabama; and although precise relations have not yet been ascertained, it is indicated not only by physical considerations but by Fontaine's recent studies in Virginia and Alabama that at least a part of the Orange Sand of Hilgard and other southern geologists is equivalent to the Appomattox formation of the north rather than the Columbia, which is not known to extend much farther southward than North Carolina. (It should be noted that a part of the deposits designated "Orange Sand" by different geologists consist of re-arranged residuary debris of the Tuscaloosa and perhaps other formations.)

Too little is yet known of the Appomattox formation to warrant minute interpretation of its history or correlation of its record either with those of other deposits of the Atlantic Slope or with the degradation records of the Piedmont and Appalachian hills.

[To be continued.]

Art. XXVIII.—*A Diorite Dike at Forest of Dean, Orange County, N. Y.;* by J. F. Kemp.

Recent workings in the Forest of Dean magnetite mine, in Orange Co., N. Y., prove it to be intersected diagonally by a dike of diorite. This rock was referred to in the Report of the New Jersey Survey for 1886, p. 107, but not until the last summer was the writer able to take the dimensions underground. The dike, about six feet in width, intersects the mine workings in the western branch at an angle of 30°, runs in unbroken width sixty feet across, and disappears in the footwall. Microscopic examination of a series of sections along its length proves it to be a very typical diorite quite similar to those described by Hawes* from Compton Falls and by Harrington† from the neighborhood of Montreal. The rock is dark gray in color, very fine grained, the component crystals being too small to be distinguished macroscopically. The spec. gravity varies from 2·925 to 2·974.

Under the microscope it is found to consist of crystals of plagioclase, hornblende and magnetite, together with certain alteration products of the first two. The hornblende is of the ordinary brown type, generally in well developed crystals showing the prism and pinacoidal faces. It is of rather light brown color, not remarkably pleochroic $c=b>a$. The individual crystals vary from 0·1^{mm} to 0·3^{mm}. In the more altered portions of the dike the hornblende is changed to a greenish mineral resembling chlorite, with threads and fernlike aggregates of secondary magnetite penetrating it. These thread-like aggregates are exceedingly minute, not over $\frac{1}{250}^{mm}$ in breadth, whereas the original magnetite is in isolated angular masses, seldom showing octahedral outlines, $\frac{1}{10}$–$\frac{1}{50}^{mm}$ in diameter. The magnetite is free from indications of titanium. The plagioclase is in rod-shaped crystals averaging 0·1^{mm} by 0·3^{mm} of irregular outline. Acicular inclusions probably apatite are not infrequent. The extreme smallness of the feldspar crystals made any attempts at separation with the heavy solutions unsuccessful. Calcite and quartz appear as secondary products, corroborating Rosenbusch's general statement in regard to the Lamprophyr group of the dike rocks.

Compared with slides of the Campton Falls dike, the feldspar and magnetite are noticeably more abundant, the hornblende less so, at the same time the crystals of the last named mineral are less elongated and smaller but much better developed. Compared with the Montreal dike much the same may

* This Journal, III, vol. xvii, p. 147. † Geol. Survey Canada, 1877–78, 439.

be said, as the latter resembles the Campton rock very strongly in structure. Specimens of each were kindly given me for comparison by Professor Hitchcock and Dr. Harrington.

The following analysis by the writer shows higher silica, than the two dikes above referred to, also more alumina and iron, but less lime. Allowing some of the lime to the horn blende, the feldspar appears to be within the oligoclase limits of the plagioclase series. A number of extinctions on $\infty P\breve{\infty}$ of from 7°–9° indicated the same.

SiO_2	48·19
Al_2O_3	16·79
Fe_2O_3	18·37
CaO	6·85
MgO	1·32
K_2O	1·11
Na_2O	5·59
Loss on ignition	2·31
	100·53
Soluble in HCl before fusion	23·5
Of this Fe_2O_3	18·0

All the iron determined as sesquioxide.

Noticing in the Report on Mining Industry, 10th Census, p. 118, Pl. XXVIII, a trap dike figured as cutting the Palmer Ore Bed near Lake Champlain, I procured specimens of the dike, but on microscopic examination they proved to be diabase.

Stray bowlders of rock similar to the Forest of Dean dike are to be seen not unfrequently in field work in the region, but no other definite locality is as yet known to the writer.

Geological Laboratory, Cornell University.

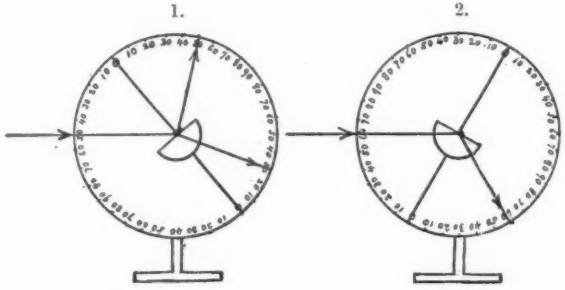
ART. XXIX.—*New Lecture Apparatus for demonstration of Reflection and Refraction;* by W. LECONTE STEVENS.

THE apparatus of which a brief description is here offered is so simple, and in every particular so much more convenient than any other designed for the same purpose, that the writer deems it worth bringing to the attention of his fellow-teachers in physics.

The refracting medium is a hemi-cylinder of crown glass, carefully polished, and mounted so as to turn on its axis horizontally. The radius is 2·5^{cm}, the length 5^{cm}. The axis passes through the center of a circle of white card-board, whose radius may be 20^{cm} or 30^{cm}. Each of its quadrants is graduated from

0° to 90°, as shown in the diagram, the diameter connecting the two zero points being perpendicular to the face of the hemi-cylinder. From a horizontal slit in front of the lantern a beam is sent through the middle of the glass and focussed on the zero-point at the further edge of the card-board, whose plane has been slightly inclined so that the path of the beam is sharply defined upon it. The incident, reflected, and transmitted beams are in the same line, the angle of incidence being zero.

The hemi-cylinder is now rotated through any desired angle, for example 50°, as shown in fig. 1. The card-board moves



with it. The room should be but slightly darkened, so that there may be no difficulty in reading the graduation on the circle. Part of the beam is reflected and part refracted. Both are plainly seen and the angles of reflection and refraction are measured. Varying the angle of incidence from 0° to 90°, one readily observes that the ratio of the reflected light to the refracted light decidedly increases. Turning still further, the beam from the lantern strikes normally on the curved surface and is totally reflected within the glass at its plane face (fig. 2). Rotating still further, the re-appearance of the refracted beam announces the critical angle, which is read upon the circle.

In the common form of apparatus where a beam is deflected by a mirror, then sent through smoky air and cloudy water, new adjustments are necessary for every variation of the angle of incidence, involving some trouble and loss of time. With the hemi-cylinder but one easy adjustment is needed for all. The higher refractive index of glass is an additional advantage, aside from the superior definition. The expense is scarcely more than that of having the hemi-cylinder made by a practical worker in glass. A small silvered mirror is substituted for the hemi-cylinder if the law of reflection alone is to be exhibited.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Spectrum of the Residual Glow.*—Crookes has examined the spectrum of the residual phosphorescent glow obtained when the rarer earths are illuminated by the electric spark in a modified form of Becquerel's phosphoroscope. The glow is observed through apertures in a revolving disk, twelve in number, symmetrically placed. On the axis of the disk is a brass cylinder, having twelve teeth at one end. An adjustable spring presses on the teeth, a second spring upon the smooth surface of the cylinder, these springs completing the battery circuit through the primary of an induction coil. By suitably adjusting the former, the spark may be made to take place at the instant when the substance under examination is visible through the aperture in the disk, or to precede it by a very short interval easily calculated. The relative length of the makes and breaks is adjusted by moving the spring to or from the bases of the teeth. Much lower vacua are necessary, since the residual gas has no phosphorescent spectrum. The phosphorescent bands in the spectrum of pure yttria do not appear at the same speed of rotation. The first to appear is the greenish-blue band $G\beta$, then the deep blue $G\alpha$, the citron $G\delta$ and the deep red $G2$; the last at a duration of 0·00175 second. At 0·00125 second $G\delta$ and $G\beta$ are equally bright and $G\eta$ just visible; and at ·000875 second all the bands are seen of their usual brightness. The author has observed that on adding strontia to a mixture of yttria and samaria and on viewing it in the above phosphoroscope with the wheel rotating rapidly, the line $G\delta$ is completely suppressed and the spectrum is identical with that of Marignac's $Y\alpha$. Alumina, giving the crimson line has a very persistant residual glow. Antimony oxide mixed with lime in the proportion of five per cent phosphoresces white with a broad space in the yellow. In the phosphoroscope the glow is green and very strong, the red and orange being obliterated. Chromium oxide with lime in the same proportion, gives a pale red phosphorescence, the red and orange being cut off in the phosphoroscope. Diamonds glowing pale blue have the longest residual glow, those glowing yellow coming next; those phosphorescing red have no residual glow. Zinc sulphide (Sidot's hexagonal blende) phosphoresces brilliantly even in a very low vacuum, with a green light. As the exhaustion is increased the edges of the crystals become blue, the two colors finally being equally bright. In the phosphoroscope, however, the blue is visible only at a high speed while the green lasts for an hour or more. The curious fact is noted that the spark spectrum of old yttrium and of the higher and lower fractions obtained from it are perfectly identical, though the phosphorescent spectra and chemical properties of the three are markedly different; and the author

discusses his sub-molecule theory and his independent element theory in regard to them. On the latter theory the spark spectrum may belong to Gδ.—*Proc. Roy. Soc.*, xlii, 111; *J. Chem. Soc.*, li, 1066 (abstr.) Dec., 1887. G. F. B.

2. *On the presence of Chlorine in Oxygen prepared from Potassium chlorate.*—BELLAMY has observed that all of those substances which when mixed with potassium chlorate facilitate the evolution of oxygen give rise also to the production of chlorine, the greater amount being set free at the commencement of the decomposition. He also calls attention to the fact that all these substances which thus favor the decomposition of the chlorate are acidic in character, and by taking up oxygen form acid oxides or anhydrides; as for example the oxides of manganese, iron, cobalt and nickel. In some cases the activity is due to admixed acidic bodies, as colcothar, which contains generally basic sulphate. The peroxides give oxygen up and take it again alternately. In the formation, even transitorily, of chromates, permanganates, etc., chlorine or its compounds must be set free and the final residue of the operation must have an alkaline reaction. If, however, the chlorate is mixed with a basic oxide such as lime, magnesia or soda, no evolution of chlorine is observable; but neither is any acceleration of the decomposition of the chlorate produced. The author represents the decomposition in presence of manganese dioxide in three stages. (A) $KClO_3 + MnO_2 = KMnO_4 + O + Cl$. (B) $(KMnO_4)_2 = K_2MnO_4 + MnO_2 + O_2$. (C) $K_2MnO_4 + MnO_2 + KClO_3 = (KMnO_4)_2 + KCl + O$.—*Ber. Berl. Chem. Ges.*, xxi, (Ref.) 3, Jan., 1888. G. F. B.

3. *On the Interaction of zinc and Sulphuric acid.*—MUIR and ADIE have studied the interaction which takes place under various circumstances between zinc and sulphuric acid. Six different grades of zinc were used, and with acids varying in concentration from H_2SO_4 to $H_2SO_4\ (H_2O)_{100}$. About ten grams of zinc and 50^{cc} of the dilute acid were used in each experiment. The reactions were effected in small flasks each connected by means of a T tube first with a flask containing an ammoniacal solution of silver nitrate and then with another containing a solution of iodic acid mixed with a little starch paste. The experiments in many cases continued for long periods, sometimes three weeks, the flasks being heated when necessary in a zinc chloride bath. The results, which are given in tabular form, show the interaction to be one of great complexity. While the action is similar for commercial and for approximately pure zinc, the quantities of sulphur dioxide and hydrogen sulphide diminishing as the zinc becomes purer, pure hydrogen being almost the sole gaseous product when the acid is diluted with ten or twelve parts of water even at temperatures near the boiling point; yet it is observed that commercial zinc continued to give small quantities of hydrogen sulphide whatever the strength of the acid and whatever the temperature. When acid of the concentration $H_2SO_4(H_2O)_2$ acts on commercial zinc at 100° scarcely any sulphur dioxide or hydro-

gen sulphide is produced; but at 165° abundance of the latter gas is evolved, and torrents of it at 180°, with but little of the sulphur dioxide. Approximately pure zinc interacting with the same acid at 160° gives both gases in abundance. With regard to the appearance of sulphur, the authors are disposed to regard it neither as a product of the interaction of SO_2 and H_2S, nor as produced by the reducing action of the hydrogen upon the SO_2; but as rather due to the mutual action of hydrogen sulphide and hot concentrated sulphuric acid. In general it appears that the interaction between approximately pure zinc and acid is chiefly a direct chemical interaction and that the products of the reactions with the less pure zincs are largely due to the occurrence of secondary electrolytic changes.—*J. Chem. Soc.*, liii, 47–58, Jan., 1888. G. F. B.

4. Organic Analysis; *A Manual of the Descriptive and Analytical Chemistry of certain Carbon Compounds in common use.* By Albert B. Prescott, Ph.D., M.D., Director of the Chemical Laboratory of the University of Michigan, etc. 8vo, pp. 533. New York, 1887 (D. Van Nostrand.)—This book appears to be a valuable addition to the literature of technical analysis. For the compounds of which it treats, it furnishes, first a systematic chemical description of these compounds, followed by the qualitative and quantitative methods to be pursued in their examination, together with tests for their purity. The titles are arranged alphabetically for convenience of reference. The references given are copious and reliable. Among the articles which seem to us especially valuable are those on the alkaloids, classified as the aconite, the cinchona, the cadaveric, the midriatic, the opium and the strychnos alkaloids; those on elementary analysis, on fats and oils, on coloring matters and on the tannins. Considerable care has evidently been exercised not only in selecting the titles so as to include substances likely to be offered for examination, but also in giving the results of the latest investigations. For clearness, completeness and accuracy, the book will add to the already excellent reputation of its author. It is provided with a full index and is printed and bound in a very satisfactory manner. G. F. B.

5. Practical Physics *for Schools and the Junior Students of Colleges;* by Balfour Stewart and W. W. Haldane Gee. Vol. I. Electricity and Magnetism. 16mo, pp. xviii, 221, London, 1888 (Macmillan & Co.)—This little book, though elementary, is one of the best of its kind in the language. The arrangement is excellent, the experiments well chosen, the descriptions and discussions clear, and the exercises admirably adapted to fix the text in the mind of the student. Morever the apparatus required is simple, much of it being constructed by the pupil himself. We commend the book to those teachers who are engaged in elementary physical laboratory instruction, as admirably suited to their needs. G. F. B.

6. *Spectrum of the oxyhydrogen flame.*—Professors G. D. LIVEING and J. DEWAR find that the spectrum of water extends with diminishing intensity, into the visible region on the one hand and far into the ultra-violet on the other. The latter portion they have photographed by means of a single calcite prism, using a long exposure. "The spectrum exhibits the appearance of a series of rhythmical groups more or less overlapping one another, and the arrangement of the lines in these groups is shown to follow, in many cases the law that the distances between the lines, as measured, in wave-lengths, are in arithmetical progression." Their researches apparently confirm the theoretical conclusions of Dr. Grünwald of Prague, for they discovered a number of lines which apparently occupy the positions which they should according to his hypothesis.—*Royal Society*, Feb. 2; *Nature*, Feb. 16, 1888, p. 383. J. T.

7. *Application of the Electrolysis of Copper to the Measurement of Electric Currents.*—In the process of standardizing Sir William Thomson's new electrical instruments, Mr. GRAY has been led to examine the accuracy of the method by means of the deposition of copper, and concludes that the constant of an electric current instrument can be obtained with certainty, by this method, to one-twentieth of one per cent.—*Phil. Mag.*, March, 1888, p. 179. J. T.

8. *Influence of light upon electrical discharges.*—Hertz in a previous number of the *Annalen der Physik* having called attention to a remarkable influence of the ultra-violet rays upon electrical discharges, E. Wiedemann and H. Ebert repeated his researches and have confirmed his results. When a spark will no longer pass between the terminals of a Ruhmkorff coil, if a beam of ultra-violet light falls upon the electrodes the spark will traverse the interval between the electrodes. Wiedemann and Ebert show that the effect is also produced by the light of burning magnesium and that the effect is confined to the ultra-violet rays; red and green producing no effect. The effect is produced at the negative electrode and not at the positive. The authors studied the effect in various gases, and at different pressures. The phenomenon varied with the pressure and with the medium. The same number of the Annalen contains a paper by W. Hallwachs on the influence of light upon electrostatically charged bodies. He finds that the ultra-violet rays modify the charge and the insulating properties of bodies.—*Annalen der Physik und Chemie*, No. 2, 1888, pp. 241–264, 301–312. J. T.

9. *Wave-lengths of standard lines.*—In a long paper continued through two numbers of the Annalen der Physik, F. KURLBAUM discusses the various methods of measurement of wave-length, and gives the results of the most refined methods which his experience has led him to adopt. His measures of the wave-length of one of the components of the sodium line, D_1, compare as follows with those of previous observers:

D_1=589, 625, Müller, Kempf.
607, 603, } Bell.
602, Peirce.
589, 590, Kurlbaum.

—*Annalen der Physik und Chemie*, No. 2,1888, pp. 381–412.

J. T.

II. Geology and Natural History.

1. *On the distribution of strain in the Earth's crust resulting from secular cooling, with special reference to the growth of continents and the formation of mountain chains;* by Charles Davison. With a Note by G. H. Darwin.—Starting from the results reached by Sir W. Thomson and independently by Prof. Darwin in regard to the rigidity of the earth, and from the conclusions of the former as to the secular cooling of the earth, Mr. Davison has gone forward and discussed the distribution of strain in a solid globe resulting from secular cooling with reference to the effect of this distribution on the great features of the earth's surface. His conclusions, as will be seen, throw much light upon what he terms "the beautiful contraction-theory of mountain evolution" to which the work of Thomson and Darwin leads up.

The author starts by supposing that the earth is bounded by a smooth, spherical surface and is made up of a great number of very thin concentric shells, each so thin that the loss of heat may be considered throughout as uniform. The first conclusions reached are:

1. "That the rate at which any shell parts with its heat increases to a certain depth below the earth's surface, where it is a maximum, after which it decreases toward the center, and the depth of the surface of greatest rate of cooling is continually increasing, and varies as the square root of the time that has elapsed since the consolidation of the globe." Also,

2. "Folding by lateral pressure takes place only to a certain depth below the earth's surface; at this depth it vanishes, and, passing through it downwards, folding gives place to stretching by lateral tension."

Accepting now, for the sake of simplicity, 174,240,000 years as the time that has elapsed since the consolidation of the earth, a period which lies well between the limits set by Sir W. Thomson and for which the depth at which the rate of cooling becomes practically insensible is 400 miles, the following conclusions are reached:

3. "(1) Folding by lateral pressure changes to stretching by lateral tension at a depth of about five miles. (2) Stretching by lateral tension, inappreciable below a depth of about 400 miles, increases from that depth toward the surface; it is greatest at a depth of 72 miles, that is, just below the surface of greatest rate of cooling; after this, it decreases, and vanishes at a depth of

about five miles. (3) Folding by lateral pressure commences at a depth of about five miles, and gradually increases, being greatest near the surface of the earth." Furthermore,

4. "Within certain limits, it is true that the depth of the unstrained surface increases as the square root of the time that has elapsed since the consolidation of the globe." Also,

5. "Folding by lateral pressure was effected most rapidly in the early epochs of the earth's history, and, since then, the total amount of rock folded in any given time decreases nearly in proportion as the square root of the time increases. The same law being approximately true of the total amount of rock stretched by lateral tension, it follows that the ratio of the amount of rock stretched to the amount folded in a given time is very nearly constant, but in reality slightly diminishing as the time increases."

While not claiming that great weight should be attached to the numerical results obtained, the author goes on to consider the effects of crust-stretching and folding on the evolution of the earth's surface features. Assuming that the formation of the great continental masses took place in the initial period of the earth's history, it follows that:

6. "Owing to the pressure of the continental wrinkles, the amount of stretching under them must have been very much less than under the great oceanic areas. Thenceforward, therefore, crust-stretching by lateral tension must have taken place chiefly beneath the ocean-basins, deepening them and intensifying their character. And, in leading to the continual subsidence of the ocean-bed, it is evidently a physical cause of the general permanence of oceanic areas; a cause, it is true, continually receding from the surface, and diminishing in intensity with the increase of time, but probably even now not quite ineffective.

"Again, the amount of crust-stretching by lateral tension being greatly in excess of the amount of crust-folding by lateral pressure due to secular cooling, it follows that folding beneath the ocean-bed will do little but diminish its rate of subsidence. The effects of folding in changing the form of the earth's surface features will therefore be most apparent in the continental areas, especially in those regions where the change of vertical pressure above the folded layers diminishes most rapidly, *i.e.*, near the coast-lines where the slope toward the ocean depths is greatest. It is perhaps worthy of remark that these are the districts where earthquake and volcanic action are now most prevalent. In the coast regions, moreover, the products of continental denudation are chiefly deposited, and the rock-folding due simply to secular cooling produces in vast masses of sediment still more crushing and folding. The direction of the folds will be perpendicular to the average slope of the surface above them, *i.e.*, they will generally be parallel to the coast-line. Hence the continents will grow by the formation of mountain chains along their borders.

"In a given time, the amount of rock-folding resulting from secular cooling was greatest in the first epochs of the earth's his-

tory, and diminished as the time increased. It does not necessarily follow that the early mountain ranges were the loftiest and most massive, but probably they were; and very possibly also, the displacement, by crushing and folding, of two neighboring portions of rock was greatest in early times. But, taking into consideration the whole surface of the globe, the process of mountain-making diminishes with the increase of the time, and so also does the rate of continental evolution.

"It cannot be said that the contraction theory on the hypothesis of solidity is entirely free from objections. Two very obvious ones have already been alluded to in the course of this paper, namely (1) The small calculated depth of the unstrained surface, especially in early geological periods; and (2) The small proportion of folded rock to stretched rock directly produced by secular cooling. But I do not think that these objections are by any means fatal to the theory. Assuming the earth to be practically solid, and to have been originally at a high temperature throughout, I believe it may be concluded that the peculiar distribution of strain in the earth's crust resulting from its secular cooling has contributed to the permanence of ocean-basins, and has been the main cause of the growth of continents and the formation of mountain chains."

In the course of his discussion the author takes up the argument of the Rev. O. Fisher on the insufficiency of the contraction theory, and gives several reasons why it should be regarded as inconclusive. The subject discussed by Mr. Davison is further considered by Prof. Darwin in a note appended to the paper of the former; he shows that some of the conclusions may be reached somewhat more simply, and furthermore makes some deductions as to the results of distortion and the magnitude of the effects accomplished. Prof. Darwin calls attention to the fact that the stretching of the earth's crust which is of importance from a geological point of view is the excess of the actual stretching above that due to rise of temperature—this if negative is a contraction and is shown by a crumpling of strata.

Assuming the time elapsed since consolidation to be 100 million years, the present depth of the stratum of no strain is two miles, and the depth is proportional to the time since consolidation. For the upper layers of the earth it is found that the integral effect is always a stretching, and this is negative; that is, it is a crumpling, as was to be expected. As to the amount of the crumpling, it is found that in ten million years 228,000 square miles of rock will be crumpled up and piled on the top of subjacent rocks. Prof. Darwin concludes:

7. "The numerical data with which we have to deal are all of them subject to wide limits of uncertainty, but the result just found, although rather small in amount, is such as to appear of the same order of magnitude as the crumpling observed geologically.

"The stretching and probable fracture of the strata at some

miles below the surface will have allowed the injection of the lower rocks amongst the upper ones, and the phenomena which we should expect to find according to Mr. Davison's theory are eminently in accordance with observation. It therefore appears to me that his view has a strong claim to acceptance."

2. *Lavas of Krakatoa.*—Prof. Judd reviews the analyses of these lavas (Geol. Mag., vol. i, 1888), and shows that they are essentially andesyte, in which enstatite predominates over the pyroxene, and that much glass is present. Yet they vary greatly in the proportions of the constituent minerals and hence widely in ultimate composition. There is a large difference also in the condition of the glassy base as to its microlites, their number, grouping, and other peculiarities. A fragment of the obsidian, on approaching a white heat, swells up as it melts into a cauliflower-like mass five or six times the size of the original, proving the presence of some volatile material which is given off at a high temperature. The amount of distension undergone was found to be $3\frac{1}{2}$ to 7, 8 or even 9 times that of the glass. The obsidian sometimes contains knots of pitchstone, the feldspar crystals of which show the effects of a large amount of corrosion, and sometimes of re-solution. Dr. Judd observes also that the stony lavas sometimes have the feldspar, pyroxenes and magnetite aggregated in little knots, producing a kind of structure which he calls glomero-porphyritic.

3. *Geologie von Bayern*, von Dr. K. Willhelm von Gumbel. First Part, *Elements of Geology.* Lieferung 5, in continuation of volume I, pp. 961 to 1088 8vo, with numerous illustrations.—Although entitled Geology of Bavaria, this work by Dr. von Gumbel so far as published is essentially a comprehensive treatise on the science. The sheets here issued treat of the Pliocene, Quaternary, and Recent periods, and then commences, on p. 1020, a new division of the work, on Geogeny or the development of the Earth.

4. *Recent contributions to our knowledge of the vegetable cell.*—Die Morphologie und Physiologie der Pflanzenzelle, von Dr. A. Zimmermann. 8vo, 223 pp. (From Schenk's Handbuch der Botanik.) Die morphologische und chemische Zusammensetzung des Protoplasmas, von Dr. F. Schwarz. 1887. 8vo, 244 pp. (In Cohn's Beiträge zur Biologie der Pflanzen. Bd. V.) Articles in current Journals, cited in the text.

The progress which modern methods of research have permitted Vegetable Physiology to make is shown by even a superficial comparison of the classical treatises of Mohl (1851) and Hofmeister (1867) with any of the recent publications on the same subject, for example, with that placed at the head of the list given above. It will be remembered that Mohl described protoplasm and first gave it its name in 1846, and therefore, at the time of the publication of his "Vegetable Cell," his attention was directed largely to the examination of the cell-contents; whereas, up to that time, a great part of the study in this field had been

devoted to the forms, markings and distribution of the structural elements. In Hofmeister's voluminous work, protoplasm and the other cell-contents receive the larger share of space, and are treated of as fully as the limitations of the methods then in use allowed.

By the application of improved processes of staining the contents of cells, and especially by the employment of the newer objectives, recent investigators have been encouraged to attack problems which it would have been thought hopeless even to approach twenty years ago. It is needless to dwell upon the fact that many of these problems have not yet been satisfactorily solved, and that not a few of them are still unanswered.

The present sketch will allude to a few of the contributions published during the last year or two, and an attempt will be made to indicate some of the relations to what has been previously known.

In extended studies by Reinke and Rodewald (1881) on the chemical character of protoplasm, it was stated that the reaction is alkaline. By careful microchemical studies of cell-contents, Schwarz (1887) has ascertained by the use of an infusion of red-cabbage that the reaction of cell-sap is sometimes acid and sometimes alkaline, but that of the protoplasmic mass is always alkaline. This alkalinity he ascribes to the presence of potassium compounds, presumably proteid combinations. The acid reaction detected in the case of old cells when all the contents are placed in contact with test paper is due to the considerable excess of acid cell-sap.

Schwarz has extended his studies to certain points regarding the structure and chemical constitution of protoplasmic contents of the cell. Recent writers have distinguished more or less completely and with considerable diversity of nomenclature, between the general protoplasmic mass of the vegetable cell and its differentiated protoplasmic contents. The latter, which are always imbedded in the former, are known as the nucleus and the chromatophores: the mass in which they are held is termed the cytoplasm. The chromatophores are three, namely, starch-accumulators, color-granules, and chlorophyll-granules. It is with the characters of the cytoplasm, nucleus and chlorophyll-granules that Schwarz has been specially engaged. Concerning the former, he says that in Cytoplasm there exists no normal network, but that a part of the mass can under certain circumstances become transformed into threads and constitute the well-known fibrillæ. Cytoplasm is to be regarded as a mixture in which under certain conditions there can be a separation of its solid, viscid and fluid substances. The microsomata (the very minute granules which occur in the cytoplasm) are sometimes of the nature of precipitates.

In the nucleus, Schwarz discriminates between (1) a fibrillar framework, (2) a basic substance, (3) nucleoli, and (4) an enveloping membrane. The chemical constituent of the framework is

termed by him linin; that of the basic substance, paralinin; that of the nucleoli, pyrenin; that of the peripheral envelope, amphipyrenin: while in the fibrillar framework is distributed chromatin. The chlorophyll granule is believed by him to possess numerous fibrillæ imbedded in a basic substance and surrounded by a plasma-membrane, but the fibrillar character is detected only when the granules are swollen by immersion in water, and a portion of the basic substance is dissolved. Schwarz distinguishes two proteids in the above, chloroplastin and metaxin. The author's earlier studjes under Pfeffer naturally led him to experiment upon the subject of precipitation-membranes and the allied one of vacuolation. He holds that when there is a mixture of two substances, one of which is soluble and the other insoluble but capable of limited enlargement by imbibition, there can be vacuolation; but in a mass of homogeneous substance there can be no vacuolation. The author has conducted many interesting experiments relative to the behavior of the different proteids with regard to digestive ferments, and also with regard to the action of various metallic compounds.

E. Belzung (Ann. Sc. nat. bot. iv, 179, 1887) has criticised Schimper's views relative to the formation of starch-grains through the agency of the starch-accumulators (leucoplasts). He states that in many instances the bodies described by Schimper could not be found, and that in many of the cases where they were seen they did not bear out Schimper's theory. In a rejoinder (ibid. VI, v, p. 77) Schimper demonstrates defects in Belzung's observations and shows that he has no reason to modify his original conclusions.

Heinricher (Mitth. bot. Inst. zu Graz, 1) has pointed out the occurrence in the tissues of certain Cruciferæ of idioblasts which he terms albuminoid-sacs. They are best seen in sections parallel to the plane of the leaf, in alcoholic material treated with Millon's reagent or in material which has been acted on by boiling water. The sacs or vesicles are more or less curved and are generally simple.

It has been known from researches by Hanstein and DeVries that when certain fresh-water Algæ are placed in a nutrient plasmolytic solution, for instance, a ten per cent solution of glucose or a twenty per cent solution of cane-sugar, the shrunken protoplasmic mass still remains living and even manifests some phenomena of growth. At this point Klebs (Ber. deutschen bot. Gesellsch., 1887, p. 189) takes up the subject, showing that it is possible to examine in this manner the mode of growth of the cell-wall. He concludes from his observations that in the case of Vaucheria the growth is by apposition in the newer walls and by stretching in the enlargement of the older walls. He examined also the relations of growth under these conditions to the surroundings, but of these results he has given only a general outline. The following statement relative to the nucleus is of considerable interest. From experiments on the cells of Zygnema and

of Funaria, in which the protoplasm was by means of plasmolysis severed into parts, it was only the segment which retained the nucleus which was capable of completely restoring the cell: the other fraction remains living for weeks, but although such segments of Zygnema form no new cell-wall and do not grow in length, they are nevertheless assimilative and accumulate much starch. He states that the physiological rôle of the nucleus is as yet wholly unknown. It is well to note that in cultures like those detailed by Klebs it is advantageous to add to the liquid one-tenth of one per cent of potassium chromate in order to prevent the appearance of destructive fungi in the nutrient solution.

Janse of Leyden has published interesting studies made at the Zoological Station at Naples, in much the same field, the difference being chiefly that he employed salt-water algæ. (Botan. Centralbl., xxxii, p. 21.)

Haberlandt (Ber. deutsch. botan. Gesellsch., v, 205) has examined the position of the nucleus in certain vegetable cells, and concludes that in most cells whose walls show a localized thickening or an increase of surface, the nucleus is in close proximity to the active portion. He finds further, that from any given wood-parenchyma cell only one thylle developes, and this on the side where the nucleus lies and where a duct is in contact: the nucleus is transferred to the thylle. The author has also studied to some extent the behavior of the nucleus in severed threads of Vaucheria. His observations, made independently of those of Klebs, have led him to about the same conclusions.

Zacharias (Botan. Centralbl., xxxii, 59) has re-examined the relations of the nucleus to its surrounding protoplasm, and finds that the latter does not enter the nucleus when division is taking place, but that there is always a distinct demarcation between the two.

Zopf has detected in the spores (conidia) of *Podosphæra oxyacanthæ*, granules hitherto undescribed. For them he proposes the name of Fibrosin-granules, and states that they probably constitute a portion of the reserve matters. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *Beiträge zur Geophysik: Abhandlungen aus dem geographischen Seminar der Universität Strassburg*, herausgegeben von Prof. Dr. Georg Gerland. 1 Band. 373 pp., 8vo. Stuttgart, 1887. (E. Schweizerbart'sche Verlagshandlung, E. Koch.)—This volume forms the first of a series to be published at intervals, perhaps yearly, as the material accumulates. It contains papers by the members of the geographical Seminar of the Strassburg University, and speaks well for the activity of a teacher who can inspire his pupils to accomplish such results. The introduction by the editor is an interesting and comprehensive discussion of the scientific scope of Geography, its various departments, and its relation to the kindred sciences of geology, anthropology, etc.

The memoirs forming the bulk of the volume are four in number. The first by H. Blink is on the winds and sea currents in the region of the small Sunda islands; a second by H. Hergesell on the change in the planes of equilibrium of the earth caused by the formation of the polar ice masses and the resulting changes in sea level; a third by the same author on the influence which a change in the geoid can have upon the relative heights of a plateau and on the fall in a stream bed; a fourth by E. Rudolph discusses submarine earthquakes and eruptions, as to their phenomena, distribution and cause, with a catalogue of observed occurrences of this kind.

2. *Klima und Gestaltung der Erdoberfläche in ihrer Wechselwirkung dargestellt* von Dr. J. PROBST. 173 pp. 8vo. Stuttgart, 1887, (E. Schweizerbart'sche Verlagshandlung, E. Koch.)—The author's discussion of this subject falls into two parts. The first embraces the consideration of the climatic conditions of the successive geological periods, and the second takes up the modifications and mutual relations between the climatic development and the form of the earth's surface. The peculiar features of the climate of the early geological periods are discussed with their causes, and a close similarity traced between this and the true ocean climate of the present day in its greater uniformity, greater warmth and peculiar distribution. The consideration of the later periods follows with an attempt at an explanation of their climatic conditions. This portion of the work offers a number of points of interest with less that admits of criticism than the following part. It is hardly possible to accept the author's estimate of the effects upon the fundamental development of the earth's features of the contraction caused by the unequal cooling of portions of the underlying earth's crust by the cold currents which form part of the sea's circulation.

3. *Beobachtungs-Ergebnisse der Norwegischen Polarstation Bossekop in Alten* von AKSEL S. STEEN. I Theil, Historische Einleitung, Astronomie, Meteorologie, 100 pp. with 4 plates. Christiana, 1887. (Die Internationale Polarforschung 1882–83).—This volume is one of numerous contributions made to science as the result of the labors at the International Polar Stations established in 1882. The Norwegian station was at Bossekop at the end of the Altenfjord, 69° 28′ N. lat. and 23° 15′ E. long. The observations made extend over the subjects of astronomy and meteorology and are given in full detail in a series of tables; the daily cause of the air-pressure, temperature, moisture, wind velocity, and cloudiness are given on the closing plates.

4. *The Asteroids, or Minor Planets between Mars and Jupiter;* by DANIEL KIRKWOOD. Lippincott & Co., Philad. 1888. 12°, pp. 60.—A very convenient summary of facts and a collection of tables of the small planets. These are followed by a discussion of the various facts shown by the tables.

5. *A Manual of Descriptive Geometry;* by C. A. WALDO. Heath & Co., Boston. 8°, pp. 77.—A book of suggestions, defi-

nitions, problems, etc., whose scope is by no means to be measured by the number of pages.

6. *Annals of the Astronomical Observatory of Harvard College;* Vol. XIII, p. ii. Cambridge, 1888. E. C. PICKERING, Director. The zone observations made, principally by Professor Searle, in the years 1882–6 with the transit wedge photometer attached to the large equatorial are here published. The stars measured are largely from the zones observed by Bond.

7. *The Movements of the Earth;* by J. NORMAN LOCKYER. Macmillan & Co. 1887, 8°, pp. 130.—A small volume, the first of a series promised by Mr. Lockyer, to give the *Outlines of Physiography.* This volume explains the various motions of the earth, and the first principles of the measurement of space and time in Astronomy.

8. *Publications of the Lick Observatory of the University of California;* E. S. HOLDEN, Director. Vol. I. Sacramento, 1887. —This volume contains a history of the institution, an account of various observations made during the progress of construction; a description of part of the instrumental equipment; and a series of reduction tables.

9. *Cordoba Observations.*—The ninth volume of the *Resultados del Observatorio Nacional Argentine,* containing the observations made under Dr. Gould's direction in 1876 has been received.

10. *Elementary Treatise on Analytical Mechanics;* by W. G. PECK. 319 pp., 8vo. New York and Chicago, 1887 (A. S. Barnes & Co.).—The important principles of analytical mechanics are presented in this volume systematically and with a good deal of clearness of arrangement though without much claim to originality.

OBITUARY.

JAMES C. BOOTH died March 21, at Philadelphia, at the age of seventy-eight. He was the author, with M. H. Boyé, of the Encyclopedia of Chemistry, published in 1844, and also of a report on the Geology of Delaware, with chemical notes. He contributed a considerable number of papers on chemical subjects, several of them in analytical mineralogy. He was for many years on the staff of the U. S. Mint at Philadelphia.

Geologie des Münsterthals, von Dr. A. Schmidt, A.O., Prof. Univ. Heidelberg. 2d part. Porphyry. 172 pp. 8vo. Heidelberg, 1887 (Carl Winter's Universitätsbuchhandlung).

Uebersich der Physiko-geographischen verhältnisse des Europäischen Russland, während der verflossenen geologischen Perioden von A. Karpinski. 44 pp. 8vo, with one plate. St. Petersburgh, 1887.

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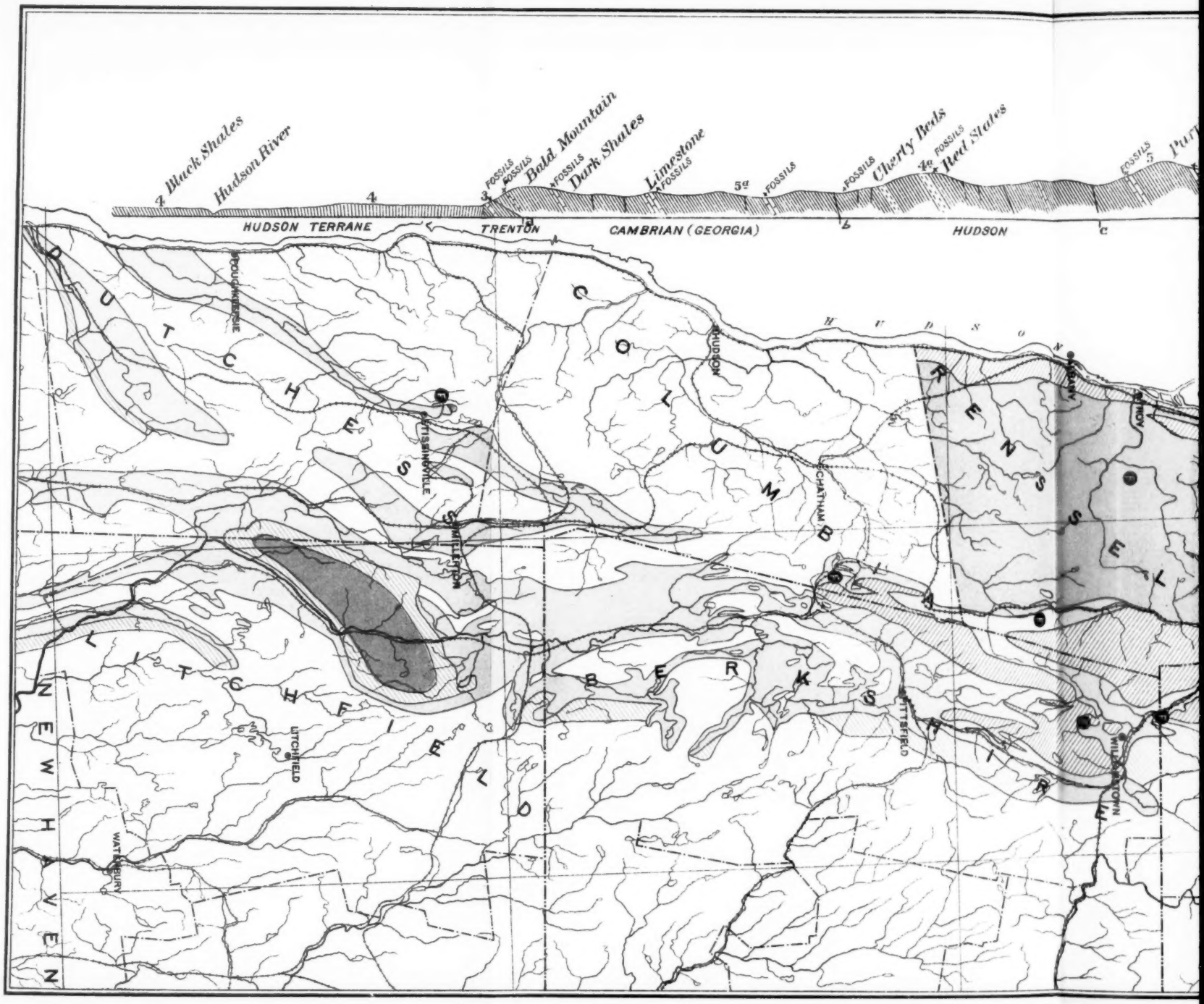
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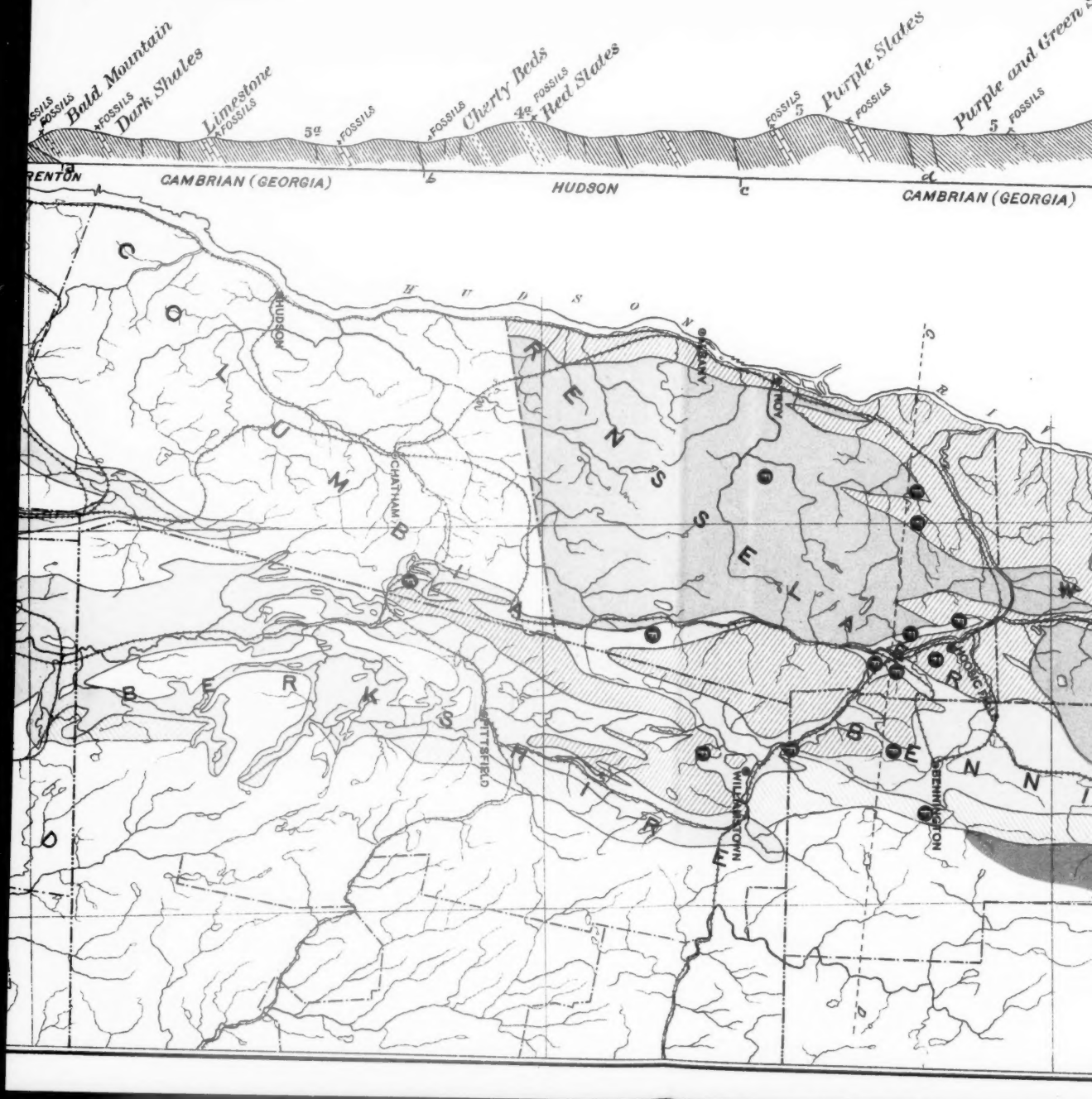
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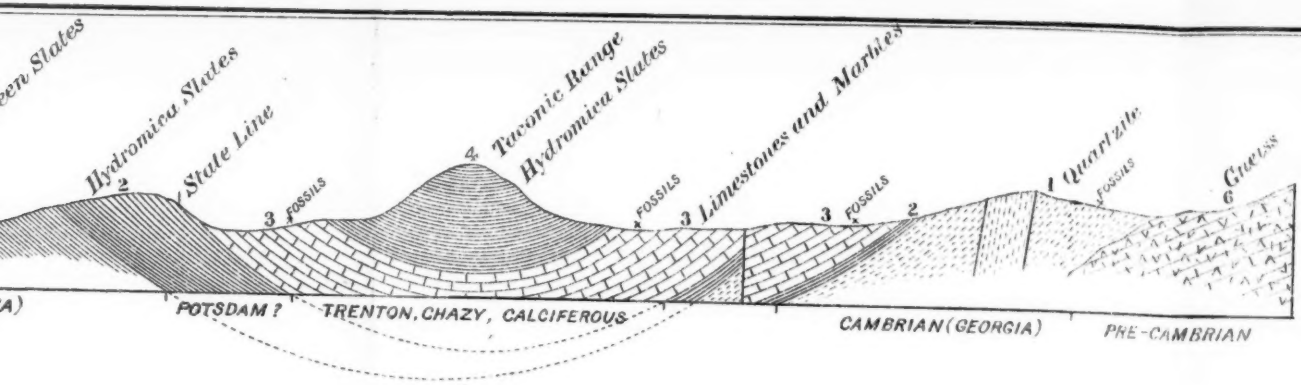
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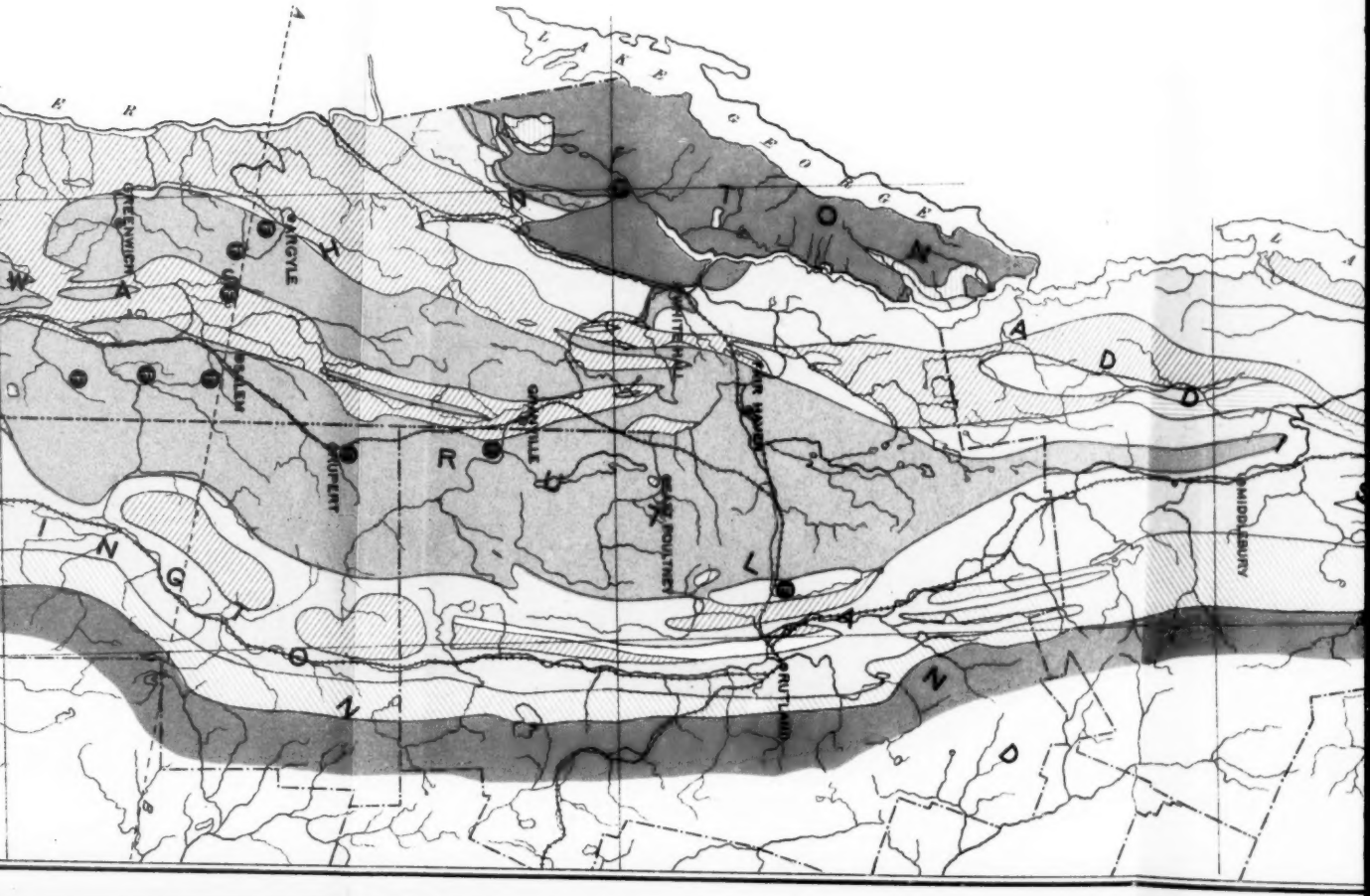
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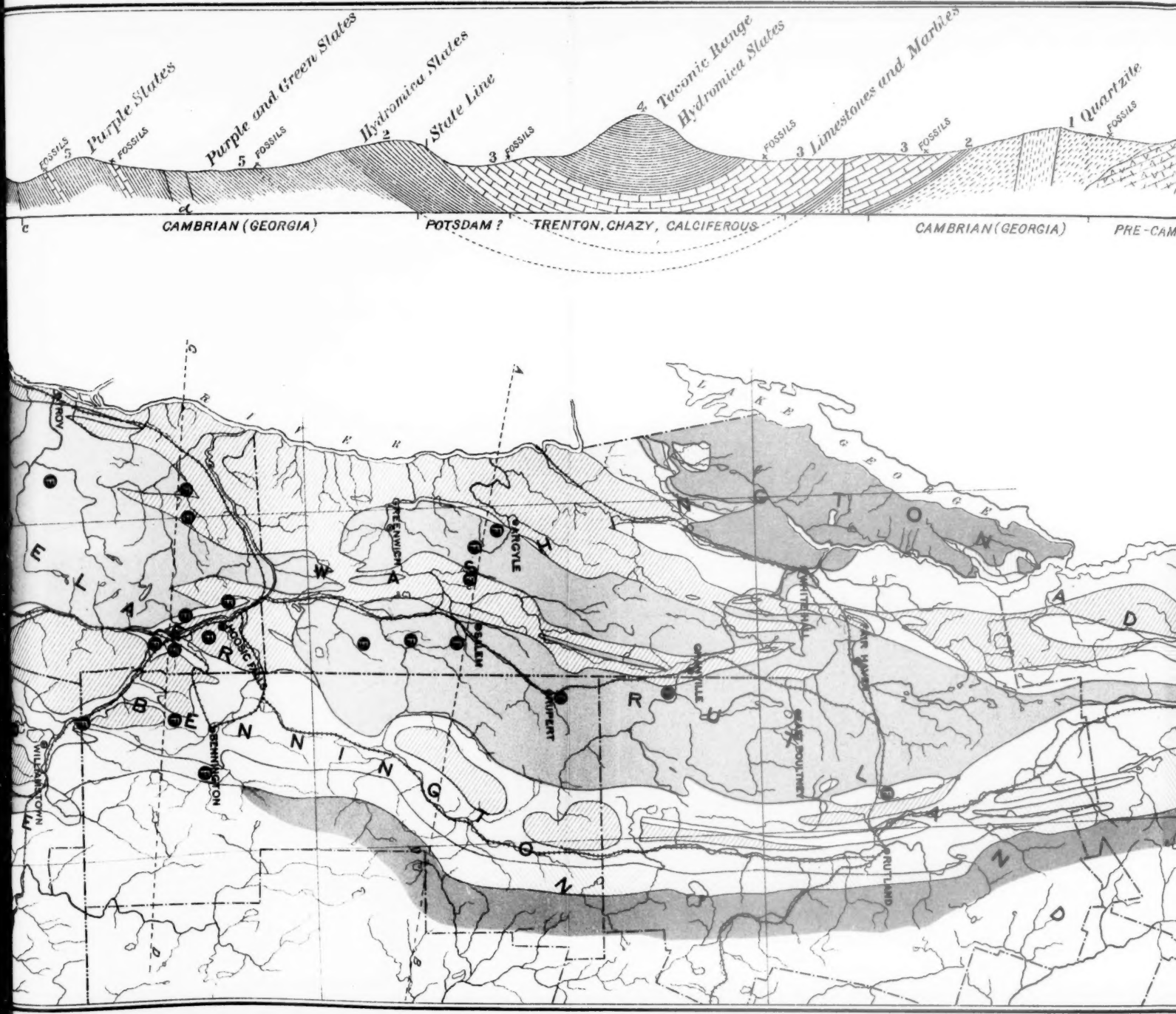
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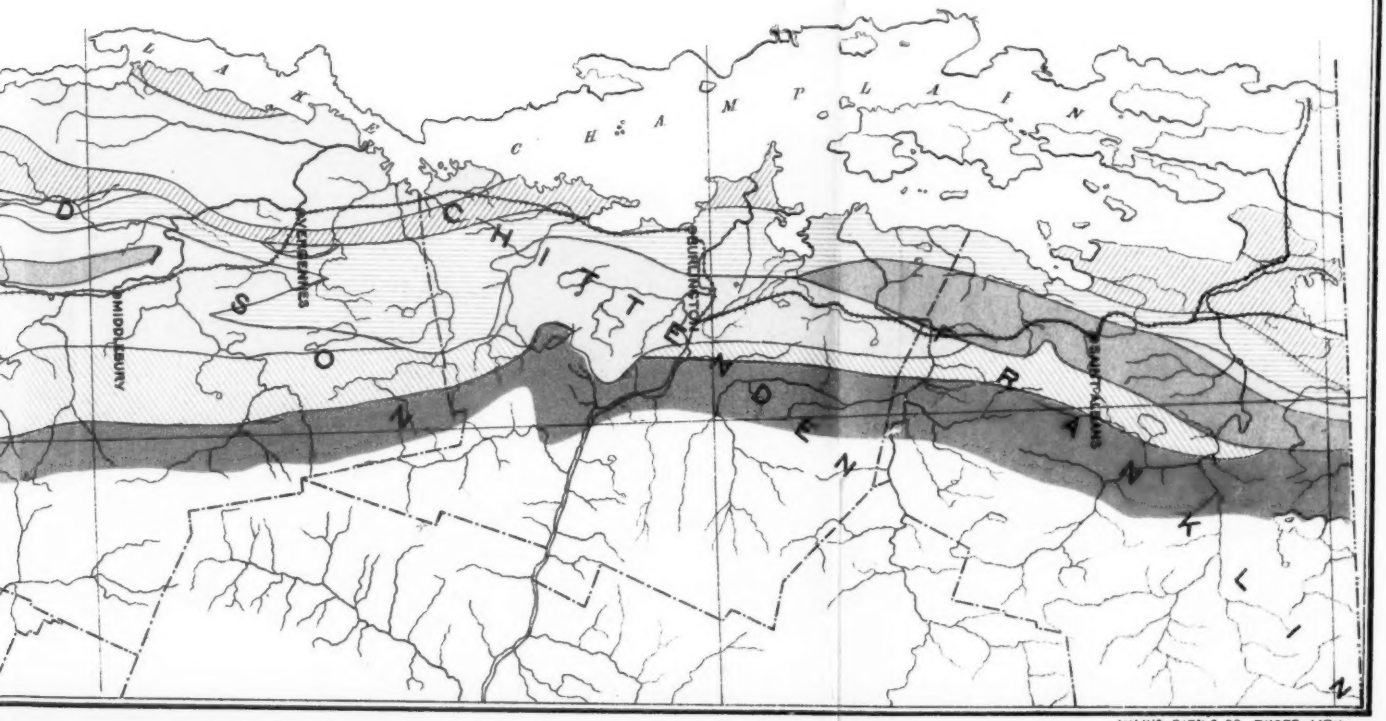

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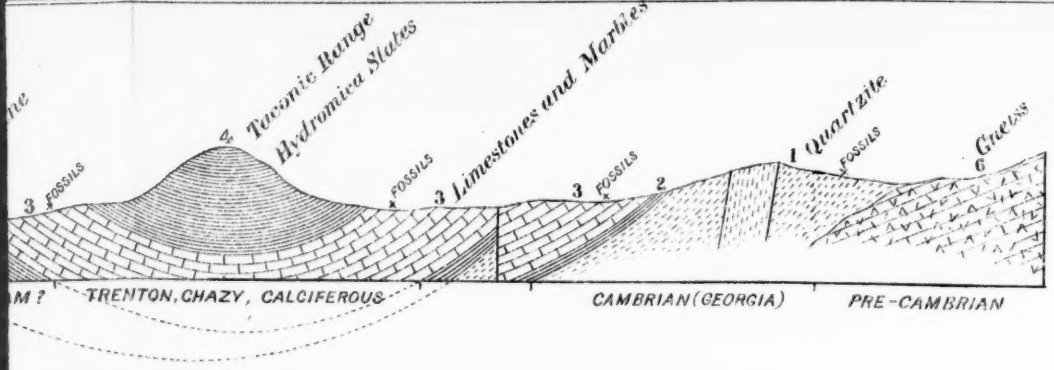
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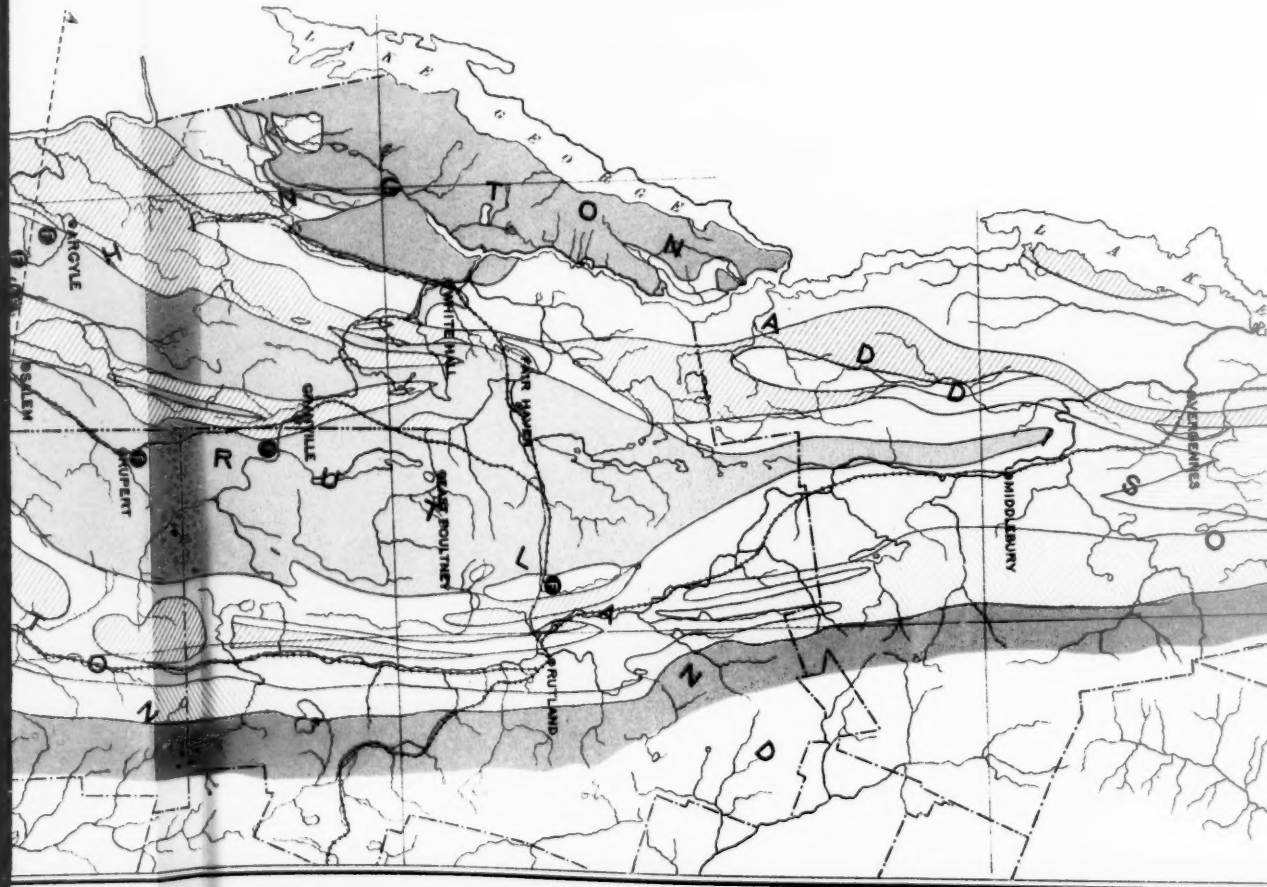
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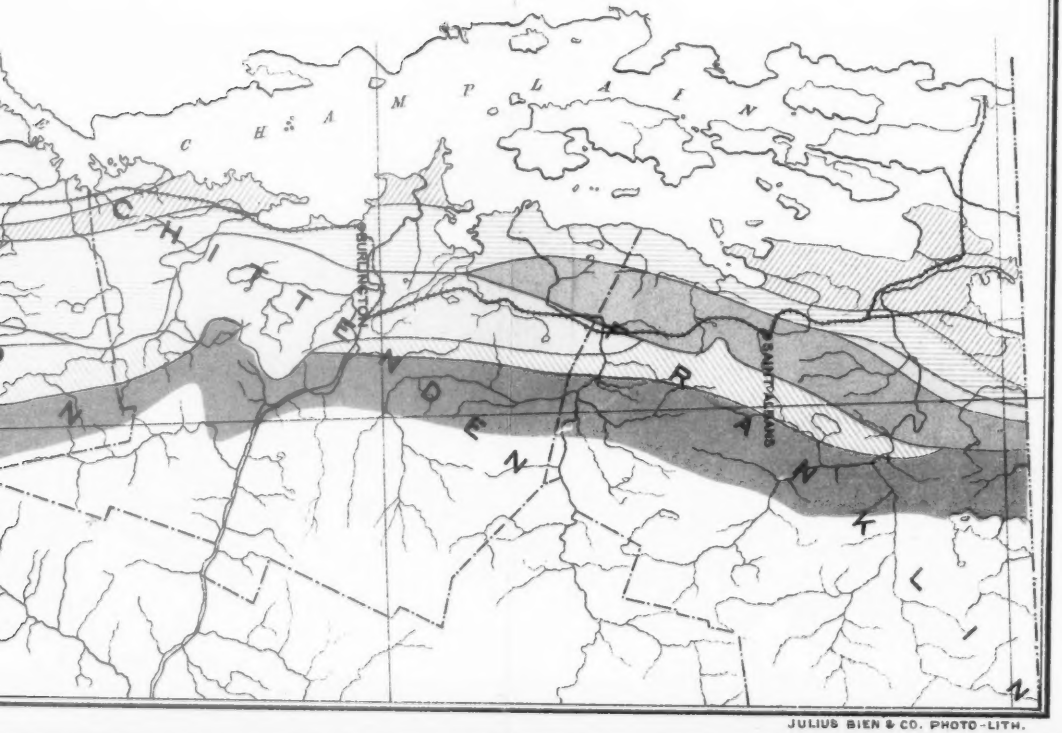

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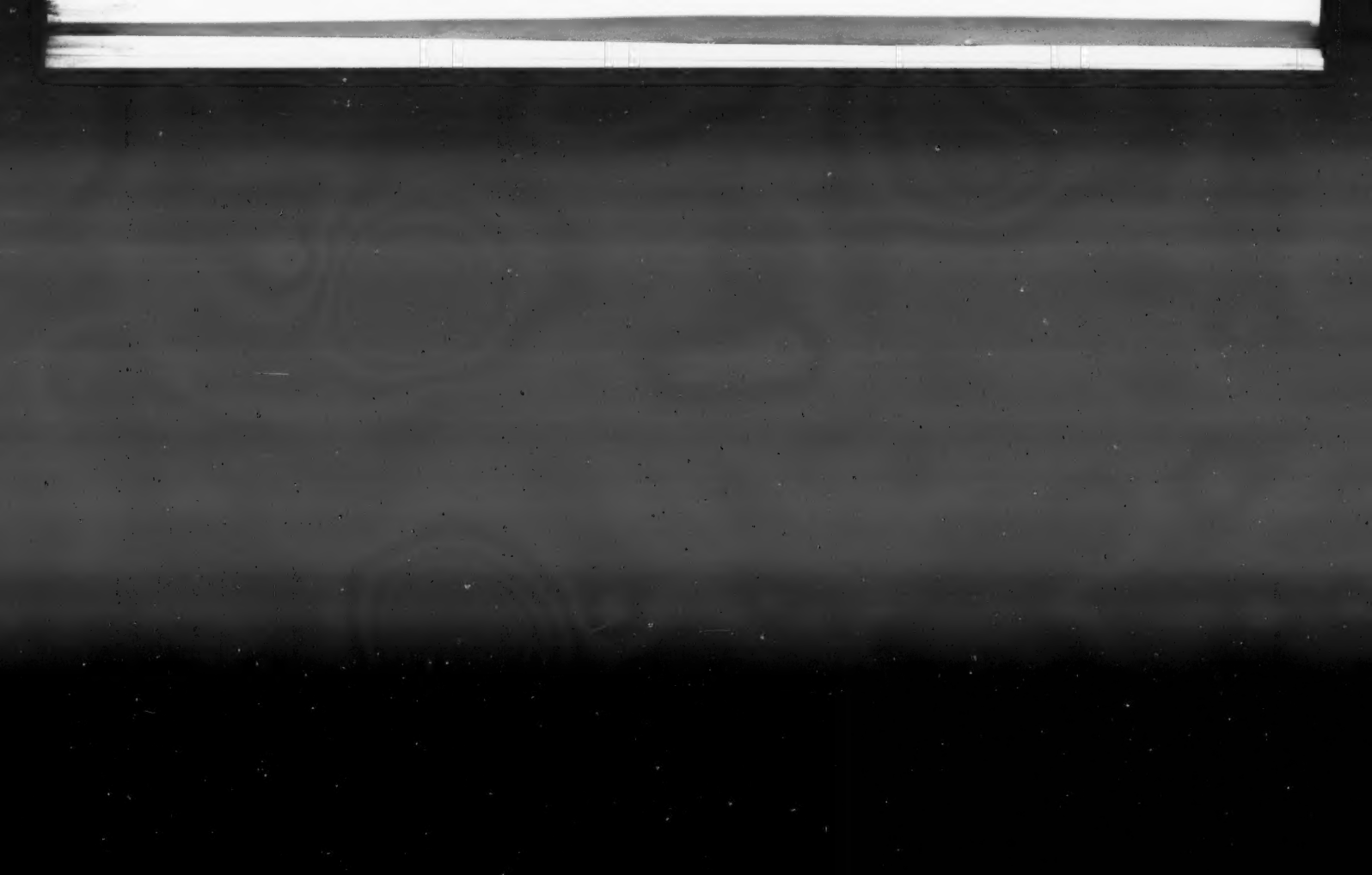

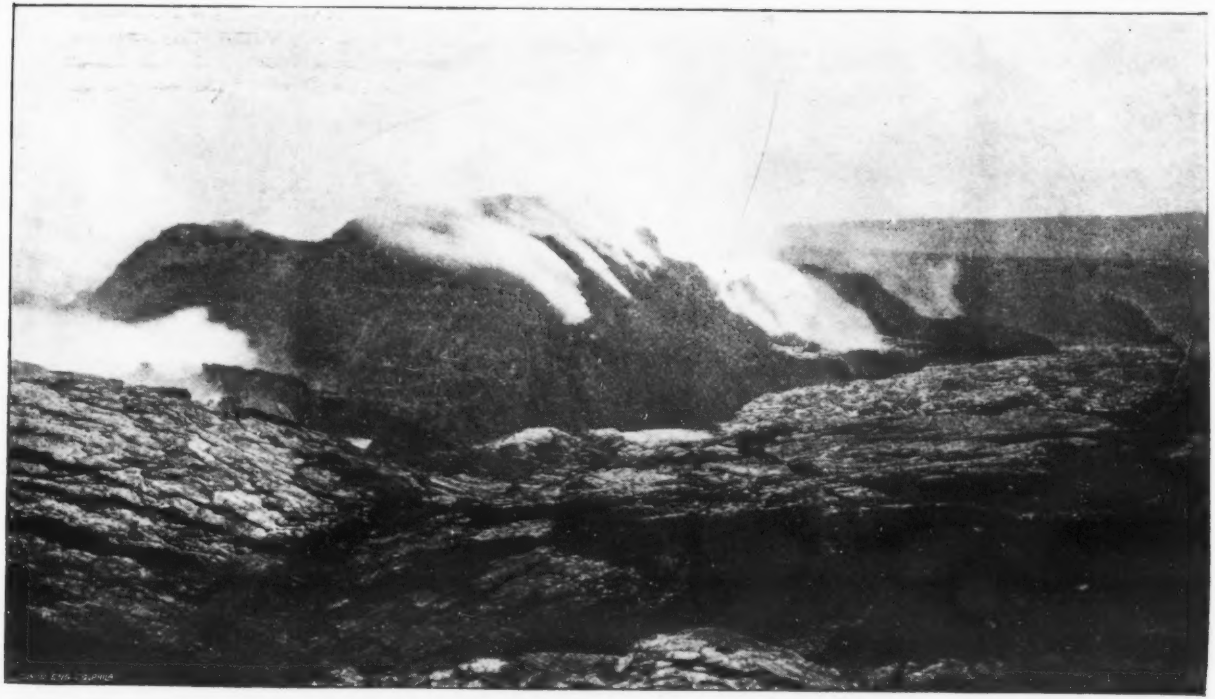

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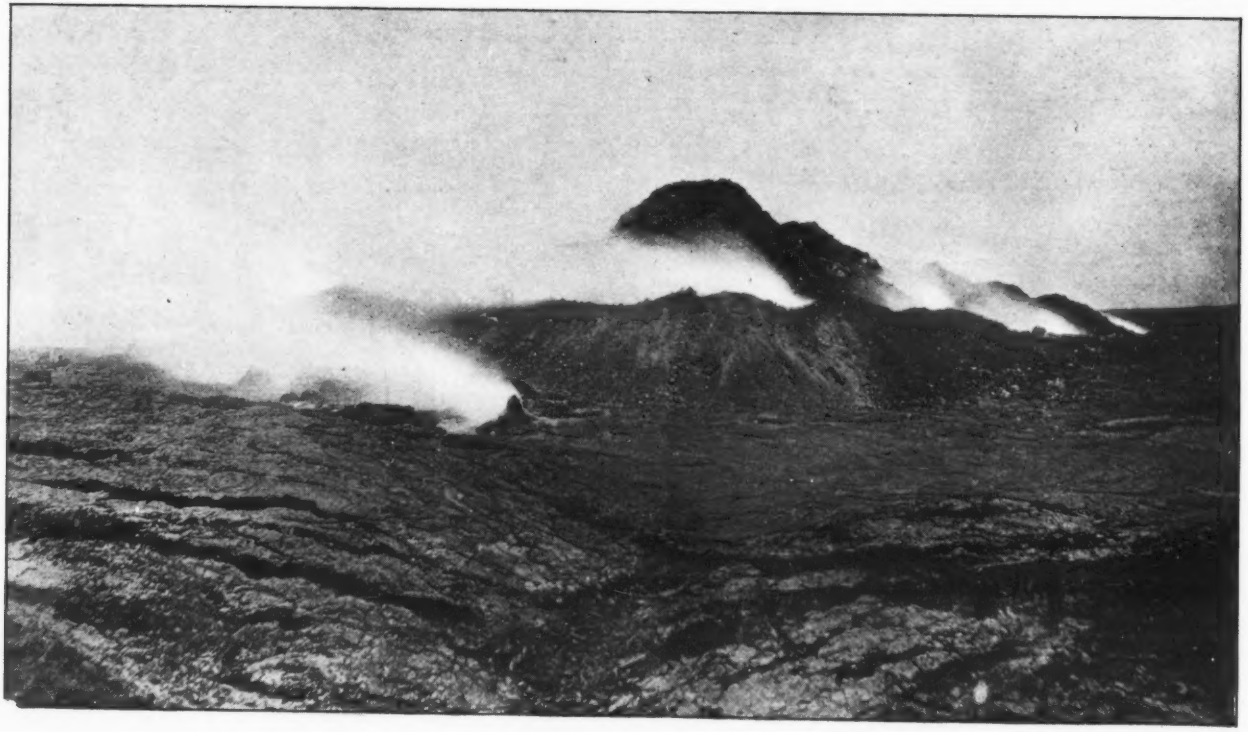

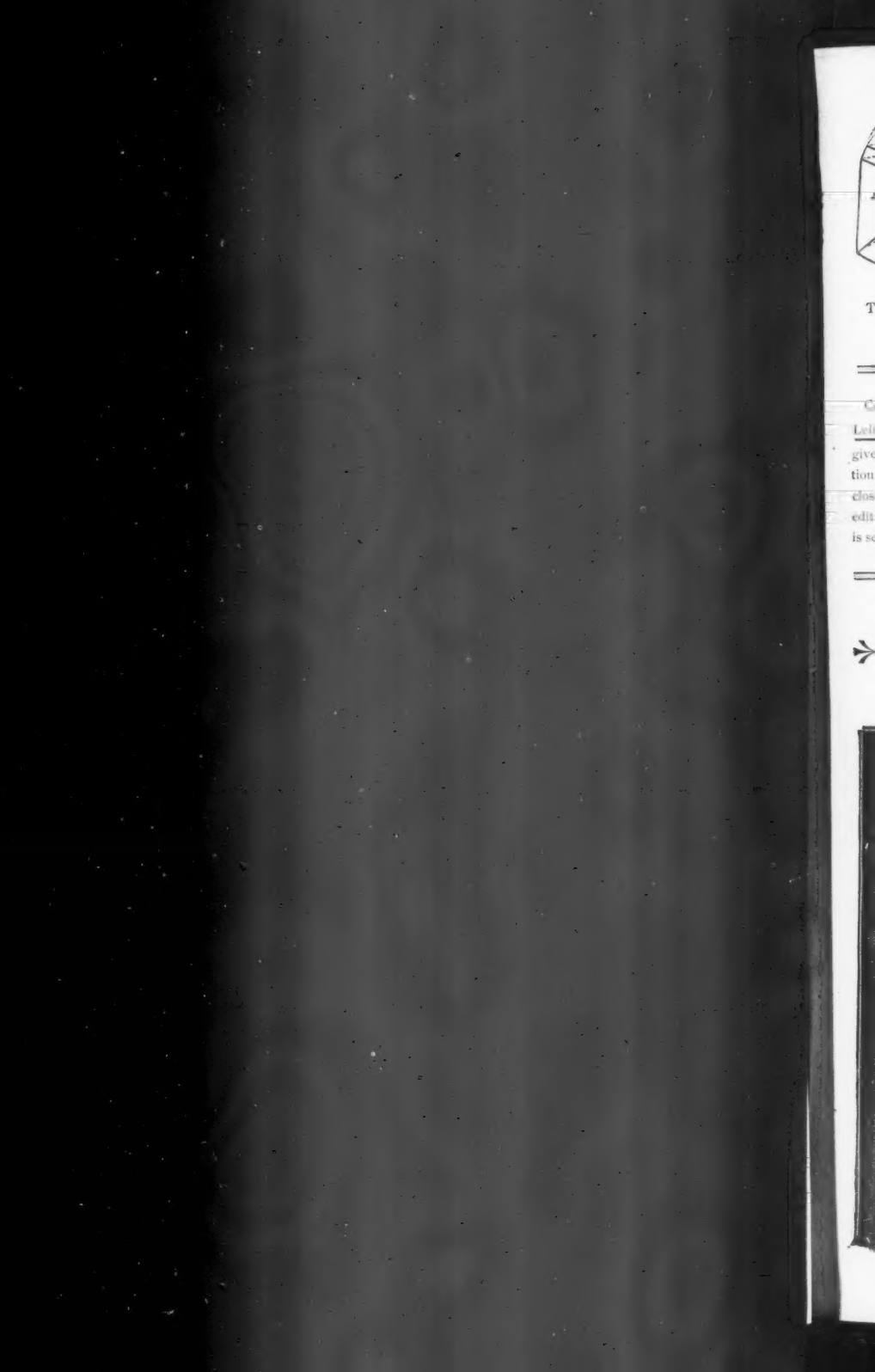

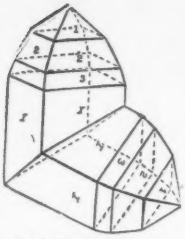

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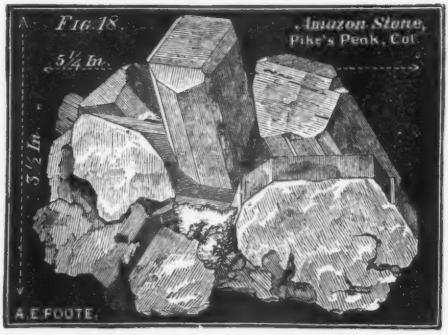

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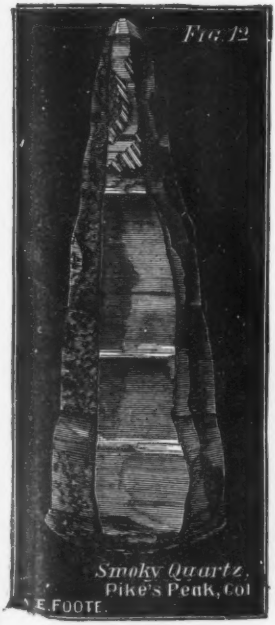

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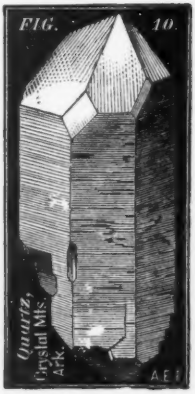

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